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Further Observations on the Effect of Heavy Stocking on the Worm Burden under a System of Rotational Grazing.

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In the spring of 1932 an experiment was set up to observe the effects of intensive grazing, by the heavy stocking of a pasture, on the worm infestation of animals, and to arrive at some estimation of the consequences of modern grazing practices. These observations covered a period of one year and the results obtained from the experiment, which was carried out by one of us, have been put forward in an earlier paper (Morgan, 1933). Some conclusions were drawn from the work but these were considered as purely provisional owing to the small scale of the experiment and to the observations covering the comparatively short period of a year. It was pointed out that the effects of overstocking would not become evident until pastures had been under a system of rotational grazing for many seasons and when the concentration of helminth ova and larvae had reached a very high level. With this in mind it was decided to proceed with observations on the effects of heavy stocking on the worm burden by setting up a fresh experiment running on lines similar to that already described but using, in places of the goats in the 1932–33 work, one-year old sheep, as it was thought that this type of stock would ensure a closer cropping on the experimental plots.

In practically all respects this second experiment was identical with the previous one and a detailed description of it will not be repeated. The observations were made on sheep grazing under what is now well known as "The New System of Grassland Management," which was described in the earlier paper (Morgan, 1933). The same pasture, with its permanent fenced divisions into plots, was used with a single alteration. The control plot which previously extended to three-eighths of an acre, an area equal to one and a half times the combined areas of the six experimental plots, was increased to cover half an acre or twice the areas of the combined six

experimental plots. This step was taken since the previous year's experience had shown that the control plot was, at times, barely sufficient to maintain the animals without additional manuring.

Neither the experimental nor the control plots were given a basal dressing of artificial manures but, starting on the 11th April, 1933, each of the six experimental plots was treated successively, at approximately weekly intervals, with a dressing of sulphate of ammonia at the rate of 1 cwt. per acre. On the 4th May, just over three weeks from the time experimental plot No. 1 had received its dressing, the sheep were put out to graze as the grass was then in very good condition. By the time experimental plot No. 6 had received its dressing on the 18th May it was decided to discontinue the addition of sulphate of ammonia as the growth of grass was becoming too vigorous for the two sheep to graze it down satisfactorily and it was deemed advisable to short circuit the movement of the animals on the experimental plots. Accordingly the sheep were transferred at the end of their week's grazing on plot No. 4 back to plot No. 1 on the 1st June and plots Nos. 5 and 6 were lightly scythed to remove the excessive growth of grass. On the same date two extra sheep, one with the experimental and the other with the control animals, were put out in order to get better cropping and later experience showed that three sheep appeared to be the number required to graze each plot closely in about seven days.

From this time onwards the rotational grazing of the six experimental plots was carried out without interruption. Sulphate of ammonia dressings were resumed on the 20th July, beginning with plot No. 1, until each plot had been treated and then discontinued as the result of exceptional conditions of drought which prevailed during the spring and summer of 1933 during which times the rainfall was far below normal and the temperature remained consistently high. The pasture began to look rather scanty by the beginning of July and as time elapsed the ground became very dry and bare and it was found necessary not only to allow the sheep to remain on each plot only three or four days instead of the normal seven but also to supplement the meagre grazing with a little hay, which was given to both experimental and control animals. It was not until about mid-September, following upon a short period of rain, that there was an improvement in the grass which, though not abundant, came into fair condition and remained adequate for the support of the animals until the experiment terminated at the end of a year's duration.

As in the previous year's experiment an indication of the worm burden of animals under rotational grazing on the experimental plots and that of the control sheep was attained by fortnightly counts of the eggs present in a gramme of faeces passed by them. The technique employed was that described in the previous paper (Morgan, 1933) except that samples of 10 grammes comminuted with N/10 NaOH and made up to a volume of 300 cc. were used instead of 6·6 grammes to a volume of 200 cc. Previous experience had shown that the condition of the faeces to be passed by the animals would vary depending upon the time of year, state of the pasture and other factors and that to obtain egg counts likely to be of comparative value some estimation of the moisture content of the faeces was necessary. Careful weighings of selected samples before and after the moisture had been eliminated therefrom showed that faeces could be grouped, from the viewpoint of consistency, as follows :—hard and soft pellets ; mushy and very mushy ; exceptionally mushy or diarrhoeic. Mushy and very mushy faeces had approximately twice as much moisture present as in hard and soft pellets, while the exceptionally mushy or diarrhoeic stools had three times the water content of formed pellets. As the condition of the faeces was noted when the fortnightly samples were taken it was possible to arrive at a truer estimate of the egg counts by multiplying the number of eggs per gramme by 1, 2 or 3 according to the consistency of the droppings. The number of eggs per gramme was obtained from the average count of three to four 0·15 cc. samples of the sodium hydroxide-faeces mixture multiplied by the constant factor of 200.

Results obtained from egg counts and weights.

It soon became evident that sheep were far less suitable than goats for the purpose of obtaining faecal samples for egg counting. While the faeces passed by the goats in the 1932–33 experiment consisted, for the greater part, of well formed pellets those from sheep were invariably mushy and often diarrhoeic. In the latter case a suitable sample was very difficult to obtain and even after allowing for these variations in the consistency of the faeces by multiplying the number of eggs per gramme by the predetermined factor it was felt that, at times, little reliance could be placed on the counts obtained as an indication of the worm infestation.

In spite of this it can be said, however, that with one exception none of the animals showed the gradual increase in eggs per gramme during the summer months and followed by a more rapid autumn rise which was a

marked feature of the 1932–33 experiment. In the case of experimental sheep No. 1 there was, on the other hand, a very rapid increase, from an already high level, at the end of August and this remained high until the animal died early in October. The post mortem examination in this case showed a very heavy infection of *Haemonchus contortus* and it was in this sheep alone that this species was met with. None of the other sheep, even those grazing on the same plots, contained *H. contortus* at autopsy and it would appear that these had become immune to this particular parasite.

The egg counts in the case of all the sheep which died also showed a definite and, in some instances, a very marked increase during the month preceding death. With the exception of sheep No. 1 these counts had remained, on the whole, at a fairly low level except for slight increases during September and October. The only animal to maintain a low count to the end of the experiment was control sheep No. 4 and this was the only one to survive.

All the sheep, which were in good condition when the experiment started, showed a very decided and gradual tendency to fall in weight throughout the observational period. Whether this was due to the lack of adequate grazing owing to the exceptionally dry season or to parasitic worms is difficult to say. As already stated the frequent scouring made egg counting somewhat unreliable and there was, in most cases, no marked increase in the number of eggs to correspond with the gradual fall in weight. It is interesting to note, however, that sheep No. 4 which has remained alive began to increase in weight from January onward although prior to that there had been a gradual fall. The egg counts in this case had fallen to a very low level towards the end of the experiment.

Results of post mortem examinations.

During the course of the experiment 5 of the 6 sheep died and post mortem examinations of the animals showed enteritis of the abomasum or intestine and congestion of the lungs, accompanied in some cases by a varying amount of serous fluid in the body cavities, to occur in most animals. No single animal had less than 5 species of parasitic helminths present and in all cases exceedingly heavy infestations of one or more species were observed, which gave the impression that death was due partly, if not wholly in some instances, to invasion by the parasites. It is significant to note that all three experimental animals died before any of the controls, a happening similar to that recorded in the previous

season's experiment. The dates of death were as follows : Experimental animals No. 1, 7.10.33 ; No. 2, 1.2.34 ; and No. 5, 25.10.33 ; Control animals No. 3, 15.3.34 and No. 6, 7.2.34. Control sheep No. 4 was still alive when the experiment terminated.

Post mortem examinations of the sheep showed the following species of helminths to be present : *Muellerius capillaris, Haemonchus contortus, Ostertagia circumcincta, O. trifurcata, Trichostrongylus axei, T. vitrinus, Bunostomum trigonocephalum, Nematodirus filicollis, Strongyloides papillosus, Chabertia ovina* and *Trichuris ovis*. One animal also harboured a single *Cysticercus tenuicollis* and two *Moniezia expansa*.

Haemonchus contortus was present only in Experimental animal No. 1. This stomach worm occurred in great numbers and over 5,500 specimens were recovered at autopsy and the gastro-enteritis resulting from this parasitic invasion appeared to be responsible for the animal's death. *O. circumcincta*, present in 3 of the sheep, was observed as a very heavy infestation in the two control animals Nos. 3 and 6. The second of these animals also had a heavy infection of *O. trifurcata*, the two species being present in approximately equal numbers, and showed extensive enteritis of the abomasum due to helminthic invasion. Another Trichostrongyle of the fourth stomach, *Trichostrongylus axei*, was encountered once in experimental sheep No. 2 where it occurred in enormous masses and had set up severe gastritis. *T. vitrinus* occurred in the small intestine of 3 animals as very light infestations in two of them but as an extremely heavy one in the third, experimental animal No. 5. *Nematodirus filicollis* was observed but once, and then only in very few numbers. *Chabertia ovina* was recovered from 4 of the sheep in the following numbers : No. 1, 19 ; No. 5, 27 ; No. 3, 603 ; No. 6, 439. *Trichuris ovis* also occurred in 4 sheep but not to any appreciable extent, 33 being the highest number recorded. The numbers of *Bunostomum trigonocephalum*, found in all the dead animals, did not exceed 15 in the experimental sheep but reached a figure of 115 in No. 3 and 517 in No. 6, both of which were control animals.

Discussion.

It is interesting to note that even when sheep are grazing on the same plot there is a surprising difference in the relative frequency of the species of worms present. In the case of the three experimental sheep the predominant species—the one which might be associated with the diseased conditions—differed in each animal. Thus in sheep No. 1, *Haemonchus*

contortus was the most common ; in No. 2, which died soon after, *Trichostrongylus vitrinus* was very abundant although no marked enteritis was observed ; in sheep No. 5, which died about three months later, *Trichostronglus axei* appeared to be causing most damage.

Amongst the tentative conclusions put forward as the result of the previous year's work was the observation that *Chabertia ovina* and the smaller Trichostrongyles tended to be the commonest species picked up during the winter months and that they appeared to have a considerable influence upon the health of the animals. The present experiment substantiates these observations. In considering the 3 sheep which died in the period 1st February to the 15th March, it will be observed that very heavy infestations of *Chabertia ovina, Trichostrongylus axei, Ostertagia circumcincta* and *O. trifurcata* occurred which points to the fact that the cold weather of the winter months apparently had not influenced their development to a marked extent, especially when, it should be pointed out, larvae in all stages of development were observed along with the adults of these species. *Bunostomum trigonocephalum,* which did not occur at all in the goats of the previous season's experiment, also seems to fall within this group of species capable of development during the winter. The severe haemonchosis which developed in sheep No. 1 lends support to the suggestion put forward in the earlier paper that the summer months appear to be more suitable for the development of *H. contortus* and its absence from the other sheep would seem to be due to an immunity having been acquired by them to this species.

In reviewing the results obtained from the 1933–34 experiment two factors, namely the exceptionally dry weather and the unsuitable state of the faeces for egg counting, make it difficult to compare these results with those obtained in 1932–33. It can still be said, however, that for older stock the autumn and winter months are the most critical to stock on heavily contaminated pastures. Nutritional factors and adverse conditions may have some bearing on these results and it should also be pointed out that young animals might well show very different results had they been used in the experiment.

Reference.

Morgan, D. O., 1933.—" The Effect of Heavy Stocking on the Worm Burden under a System of Rotational Grazing." *J. Helminth.*, xi (3), 169–180. (*W.L.* 11224b.)

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The Nematodes of Sheep in Manawatu District, New Zealand.

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INTRODUCTION.

PARASITIC nematodes of sheep are abundant in many parts of New Zealand, particularly in the areas of high rainfall in the North Island. Despite their economic importance, however, they have received little attention in this country and the relevant literature is small.

The indigenous mammalian fauna of New Zealand is composed of two species of bat. There are consequently no native species of mammal which might serve as a source of parasitic infection for introduced domestic stock or act as reservoirs of infection for introduced parasites.

A number of factors have operated to select the established parasitic fauna of farm animals in New Zealand. There has been the country of origin of the foundation stock. In respect to sheep, most importations have been made from Great Britain and Australia with the result that in New Zealand the selection of species of parasite of sheep is very similar to that found in these two countries. The isolation of New Zealand has been another factor instrumental in selecting the type of parasite found in domestic stock. According to the habits of various parasites, the barrier of the Tasman Sea has been effective to a varying extent in influencing their entrance to this country. Those species which spend but a short portion of their life cycle as parasites or are transient feeders on one host have been at a disadvantage in following the migrations of their hosts. Permanent parasites and those which exist on a single host for a long period have been better able to make the journey. In the case of those of sheep, Trematoda, Cestoda, Acarina, Anodura and *Melophagus ovinus* fall in this group.

Modern quarantine measures are a further obstacle to the entrance of external and some internal parasites to a country, for dips and medicinal

treatment may be applied with effect. As a rule internal parasites are with difficulty excluded for their presence in stock in process of introduction is difficult to ascertain when they are in small numbers and they are relatively invulnerable to medicinal treatment. In these respects the prevention of the entrance of nematodes of sheep into New Zealand provide a particularly difficult problem.

Once parasites have negotiated the Tasman Sea, a number of factors operate to influence the success of colonization. Those which require the services of intermediate hosts are limited in their distribution by the availability of intermediate hosts. Thus various protozoan, trematode and cestode parasites of stock in other countries are unable to gain a footing in New Zealand through lack of suitable intermediate hosts. In the case of Nematodes of sheep, only a few species require the services of intermediate hosts and the limits to their success in establishment in New Zealand depend largely on other factors, *e.g.*, climate, intensity of the population of their normal host, and the types of farming practised.

Description of Manawatu District.

For the purpose of this account, Manawatu district is regarded as that portion of the basin of the Manawatu River which is contained by Southern Oroua, Kairanga and Manawatu counties. It has an area of six hundred and fifty-one square miles, of which the great portion is alluvial, having arisen as the delta plain of the Manawatu river. An extensive portion in the close vicinity of the Manawatu river is not more than 100 ft. above sea level. In the hilly country of the northern part of the district altitudes reach a few hundred feet, but even here a relatively small area rises more than five hundred feet above the sea level. Four hundred and ninety-one square miles are under cultivation, this area consisting mainly of permanent pasture.

The soils of the district range from clayey silts to sandy loams inland, while along the coast there is a narrow sand dune area in process of reclamation. They are for the most part fertile and of fairly heavy stock carrying capacity, it being a common practice in some parts for seven ewes per acre to be grazed. The district is devoted mainly to sheep farming and dairying which may be conducted either as separate or more often as combined pursuits.

The climate is temperate and, although the seasons are well defined, it is not characterised by severe extremes. Rainfall is moderate and evenly

distributed throughout the year. In the summer and autumn it is insufficient to prevent parching of grass land. Summer temperatures are not excessive and, in the shade, they seldom rise above 80°F. Frosts extend over 9 to 10 months of the year and within the last six years, in the records available, a temperature as low as 15°F. has been reported only once.

Development of Sheep Farming in Manawatu District.

Following the clearing of the bush the sheep industry developed rapidly so that by 1890 the population of sheep had attained a figure similar to that of to-day. At present, there are approximately 458,000 in the district.

Sheep were introduced into New Zealand in 1814 but probably it was not until after the introduction of the Romney breed into this country that they reached large numbers in Manawatu district.

The Romney breed is at present the most numerous one in this district.

Previous Records of Nematodes in Sheep in New Zealand.

Few previous records exist of the species of Nematode found in sheep in New Zealand. Thomson has collected these records which relate to the earliest dates that a number of species have been found in New Zealand. It is probable, however, that those species and more have been present in the country for a great number of years. In view of the early beginning and rapid development of sheep farming in Manawatu district, it is likely that the nematodes now recorded from this district have been present for many years.

Reservoirs of Infection of Nematodes of Sheep in Manawatu District.

The reservoirs of infection that exist in Manawatu are provided by introduced domestic and wild animals. Cattle are of chief importance in this respect and in Manawatu they number about 115,000. Horses are the only other domestic stock capable of harbouring sheep parasites and as *Trichostrongylus axei* is the only parasite mentioned in the literature as common to sheep and horses, the latter may be regarded as unimportant.

In Manawatu district wild animals include red deer, zamba deer, rabbits and hares. The deer are confined to the coastal sand dune area and the bush country in the hills on the borders of the district, in which areas they are unimportant reservoirs of infection.

Rabbits are numerous, but as they have been credited with carrying only one species of Nematode of the sheep, *Trichostrongylus colubriformis*, and as this one is already distributed throughout the district, they may be regarded as of little significance in this respect.

With the less numerous hare, the same applies as for the rabbit.

Results of Author's Survey.

The results contained herein have been derived from post mortem examinations made on some hundreds of sheep for the most part from Manawatu district. Some information has been forthcoming relating to nematodes of sheep in South Auckland and other districts. This has been included, but in so far as it is concerned, no conclusions have been drawn.

In respect to Manawatu district, the sources from which material for examination was obtained were Longburn Freezing Works, Palmerston North Municipal Abattoirs, Massey Agricultural College farm and farms from other parts of the district.

The notes relating to each species given in the list below make mention of their location in the sheep and the greatest numbers found. In some cases the males only were counted. Many of the animals examined had been slaughtered when in good condition for food purposes and in these cases it was possible to obtain an indication of numbers of each species with which a sheep might be infested without the production of visible signs of injury. In animals which had succumbed to parasitic gastritis most frequently several species were involved and the relative importance of each was difficult to determine. No reference to the percentage of animals infested by a particular species will be made for it was apparent early in investigations that rhythms in the occurrence and numbers of species took place, so that the incidence of a particular species varied with season and the age of the sheep. The percentage of animals infested by a species was not an always accurate indication of its numbers nor of its relative importance. Therefore, information relating to percentage infestation of sheep in respect to particular species will be reserved for a later account when reference will be made to the dynamic aspects of worm numbers in sheep.

Unless indicated to the contrary, remarks relate to the Manawatu district only.

The order is based on the classification of Yorke and Maplestone.

Strongyloides papillosus (Wedl, 1856) Ransom, 1911.

Distribution :—Manawatu County.

S. papillosus was found in the duodenum and the jejunum of lambs and hoggets. It was a common parasite but its numbers in individual infestations did not attain more than a few hundreds. The species is apparently of little economic significance.

Trichuris ovis (Abildgaard, 1795).

Distribution :—Horowhenua, Kairanga, Kiwitea, Manawatu, Ohinemuri, and Waikato Counties,.

T. ovis occurs in the caecum. It is the exception rather than the rule for it to be absent from lambs of the order of six months of age when almost one hundred per cent. may be infested. The greatest number found to occur in any one sheep was 22 and did not seem to cause it noticeable harm.

Capillaria longipes Ransom, 1911.

Distribution :—Manawatu district.

A small number of individuals of *C. longipes* was found in the ileum of each of a few sheep. The species is economically unimportant.

Oesophagostomum venulosum Rudolphi, 1809.

Distribution :—Kairanga County.

The adult worms of *O. venulosum* were found in the caecum and the colon in both of which regions it occurred unattached to the intestinal wall. It was present in those parts of the colon in which the faeces had not yet become formed.

In New Zealand this species has been confused with *O. columbianum* and in view of the fact that it has been reported not to form nodules in the wall of the gut during its larval stage, its true identity is noteworthy.

O. venulosum was found not to be uncommon though its incidence and numbers were low. Usually only a few individuals would be obtained from a sheep, and not more than 26 have been found in one sheep at any time. It apparently causes little harm to sheep.

O. columbianum Curtice, 1890.

Distribution :—Horowhenua County, Manawatu district, Ohinemuri County.

Adults of *O. columbianum* have a similar distribution in the alimentary tract to that of *O. venulosum*. Occasionally infestations involving small numbers were found.

Chabertia ovina (Fabricius, 1788 or 1794).

Distribution :—Franklin, Horowhenua, Kiwitea, Ohinemuri, Waikato and Waipa Counties, and Manawatu district.

Chabertia ovina occurs in the colon where it attaches itself firmly to the wall of the gut. Its incidence is high, particularly among lambs in which it may be close to one hundred per cent. Its numbers, compared with those of other species, are relatively small, 102 being the greatest number found in any single infestation. A catarrhal condition is often found in the part infested by this species but despite this, when present alone, it appears to cause little trouble to the host. It is probable that as a factor tending to accentuate effects due to other causes, it is important.

Bunostomum trigonocephalum (Rudolphi, 1808).

Distribution :—Manawatu district.

B. trigonocephalum was found in sheep of less than two years of age. It occurred throughout the greater part of the small intestine. In Manawatu district it was infrequently met and its numbers were small. In two lambs respectively 27 and 20 worms of this species were found but it was usually the case that infestations contained only odd individuals. Although it has a low incidence, however, it is distributed throughout the district. The species is of little economic importance in Manawatu district.

Trichostrongylus axei (Cobbold, 1879).

Distribution :—Kiwitea County, Manawatu district.

This species occurs in the abomasum, but on one occasion it extended its area of infestation to the duodenum where several hundred worms were found. Greatest numbers of this species were obtained from animals of less than two years old and particularly in lambs of 9–12 months of age in which the incidence was high.

In fat lambs of 5–6 months of age and not exhibiting symptoms of infestation, 1,300 and 500 worms respectively were found in separate infestations.

Although *Trichostrongylus axei*, *T. colubriformis* and *T. vitrinus* might be present in a particular flock of lambs all of similar age, they did not all

infect each individual. Sometimes in the cases of *T. colubriformis* or *T. vitrinus* a single species would occur and more often two species would occur together, there being no rule as to which one should be missing. It was the rule, however, for infestations to consist of two or three species.

It would appear that factors operated within the previously uninfected lamb, to select the *Trichostrongylus* species which occurred in the infestation.

T. colubriformis (Giles, 1892).

Distribution :—Kiwitea, and Raglan Counties, and Manawatu district.

This species occurred chiefly in the small intestine, but occasionally numbers were found in the abomasum. The greatest number of males found in any infestation was 680.

It is an important parasite of the district.

T. vitrinus Looss, 1905.

Distribution :—Franklin, Kiwitea and Raglan Counties, and Manawatu district.

This species occurred both in the abomasum and in the small intestine ; the latter being the favoured region of infestation. Its incidence and numbers were greater than those of any other *Trichostrongylus* sp. encountered, it being seldom absent in lambs of 6 to 9 months of age. 3,670 males were the greatest numbers found in one sheep. This species, which is distributed throughout Manawatu, is an important parasite of the district.

T. capricola Ransom, 1907.

A few males which were believed to be of this species were found in South Auckland district.

Haemonchus contortus Rudolphi, 1803.

Distribution :—Franklin, Horowhenua, Ohinemuri, Raglan, Waikato and Waipa Counties, and Manawatu district.

This species occurs in the abomasum of sheep of all ages. Its incidence in lambs was high but numbers were relatively small, in most infestations there being a few individuals only. The largest infestation was found in a mature ewe in which approximately 1,000 worms occurred. Among lambs no infestations exceeded 800 in number.

Haemonchus contortus is distributed throughout the district.

Ostertagia circumcincta (Stadelmann, 1894).

Distribution :—Franklin, Horowhenua, Kiwitea and Raglan Counties, Manawatu district.

This species occurs in the abomasum chiefly in lambs and hoggets. It applies itself to the mucous membrane in the vicinity of the pyloric valve. The incidence among lambs of 3–6 months of age was in the vicinity of one hundred per cent. and numbers in infestations often reached several thousands. In fat lambs of 3–6 months of age, combined infestations of *O. circumcincta* and *O. trifurcata* of the order of 2,000 were found, and apparently causing little harm. *O. circumcincta* is distributed throughout the district.

O. trifurcata Ransom, 1907.

Distribution :—Manawatu district, Raglan and Waipa Counties.

This species, an associate of *O. circumcincta* in the abomasum, has similar habits, incidence, and distribution to that species, its numbers are, however, much smaller. The largest infestation found was combined with that of *O. circumcincta*, the males numbering 230 of *O. trifurcata* and 710 of *O. circumcincta*.

O. ostertagi (Stiles, 1892).

Distribution :—Manawatu district.

This species was found once in the abomasum of a lamb which had been grazing on pasture previously occupied, only, by cattle. It did not occur in large numbers.

Cooperia curticei (Railliet, 1893).

Distribution :—Franklin, Horowhenua, Kiwitea, Ohinemuri and Raglan Counties, and Manawatu district.

This species occurred in the small intestine, in the jejunum, for the most part in sheep of less than two years of age. Its incidence was found to be high, particularly during the two tooth stage. Numbers in individual infestations were frequently found of the order of 3,000 though very often they were smaller than this figure. As many as 7,000 individuals were found in an infestation, a figure greater than that for any other species of the small intestine. It is distributed throughout the district.

C. oncophora (Railliet, 1898).

Distribution :—Manawatu district.

Cooperia oncophora occurred in the jejunum of lambs. Both its incidence and numbers were low, the largest infestation containing 190 males.

C. punctata (v. Linstow, 1907).

Distribution :—Manawatu district.

This species was found once in the small intestine of a lamb which had been grazing on pasture previously occupied only by cattle.

Cooperia sp.

Distribution :—Manawatu district.

An unidentified *Cooperia* sp. was found occasionally associated with *Cooperia oncophora* and to occur in numbers of order similar to that species. The greatest number of males found of this species in one infestation was 46. No symptoms were exhibited by the infested animals.

In the matter of distribution, similar remarks are applicable to this species as to *O. oncophora*.

Nematodirus filicollis (Rudolphi, 1802).

Distribution :—Franklin, Horowhenua, Raglan, Thames, Waikato and Waipa Counties, and Manawatu district.

Nematodirus filicollis was found to be a common parasite of the small intestine of lambs, both the jejunum and ileum being infested, and occasionally it would occur in small numbers in the abomasum. In Manawatu, incidence and numbers were high in lambs of 3 to 6 months of age, amongst which no individual was found uninfested. Frequently numbers of the order of 2,000 to 3,000 of *Nematodirus* spp. occured in young lambs—the largest number found in one animal being 5,000. 1,300 males have been found in an infection.

In the absence of information on the habits of this species, it is at present difficult to estimate its economic importance.

N. spathiger (Railliet, 1896).

Distribution :—Manawatu district, Ohinemuri County.

This species also occurs in the small intestine of lambs and was commonly found in Manawatu district. Its incidence was high, but less than that of *N. filicollis* and its numbers were smaller. The largest infestation of this species contained 1,560 males. It is distributed throughout the district.

N. abnormalis May, 1920.

Distribution :—Manawatu district, Ohinemuri County.

This species has been found occasionally in Manawatu in numbers smaller than *N. filicollis* and *N. spathiger*. In one case the male population amounted to 23 individuals. It is incompletely distributed throughout Manawatu, but whether this is due to non-suitability of the climate or to incomplete distribution, is uncertain.

N. helvetianus May, 1920

Distribution :—Manawatu district.

A single male, believed to be of this species, was found in a mixed infestation containing *N. filicollis*, *N. spathiger* and *N. abnormalis*.

Dictyocaulus filaria (Rudolphi, 1809).

Distribution :—Manawatu district.

Adults of *Dictyocaulus filaria* were commonly found in the smaller bronchial tubes in lambs 5–9 months of age, *i.e.*, during the autumn and early winter. The species occurs throughout the district. A few individuals only seem to suffice to produce pneumonia, so that the species is of considerable importance in the district.

Muellerius capillaris (Mueller, 1889).

Distribution :—Manawatu district.

This species is of common occurrence, the pin head nodules to which it gives rise being found in large numbers, sometimes hundreds, in the lungs of sheep of various ages. It causes little apparent harm, but occasionally it has been associated with pneumonia in lambs, though doubtfully the causal agent.

The Relative Numbers of the Different Species.

The following species occur in greatest numbers in Manawatu district :—*Ostertagia circumcincta, O. trifurcata, Trichostrongylus axei, T. vitrinus, T. colubriformis, Nematodirus filicollis, N. spathiger, Cooperia curticei.*

Species which occur in smaller numbers and cause injury to sheep :—*Dictyocaulus filaria, Muellerius capillaris, Chabertia ovina.*

Species which occur in smaller numbers and individually cause little injury to sheep, though collectively they add appreciably to the effects of infections in sheep :—*Haemonchus contortus, Bunostomum trigonocephalum, Trichuris ovis, Oesophagostomum venulosum.*

Species found only occasionally or in small numbers:—*Capillaria longipes, Strongyloides papillosus, Oesophagostomum columbianum, Nematodirus abnormalis, N. helvetianus, Cooperia oncophora, C. punctata, Cooperia* sp., *Ostertagia ostertagi.*

The Degree of Saturation of Species in Manawatu District.

Despite the fact that Manawatu has carried a population of sheep similar to that existing at present for many years, it is apparent that so far as some Nematode species are concerned, the district is not saturated. It has been necessary to distinguish between those species which are not completely adapted to the district and those which are still in process of dissemination. Some species which occur in small numbers, *e.g., Haemonchus contortus, Bunostomum trigonocephalum* and *Oesophagostomum columbianum* are well distributed throughout the district and have a fairly high incidence. These are regarded as being incompletely adapted to the environment. On the other hand, certain species, *e.g., Cooperia oncophora, C. punctata* and *Ostertagia ostertagi,* have not been found throughout the district and compared with the species to which reference has been made just previously, have occurred in relatively large numbers. Direct evidence of the incomplete distribution of these species was afforded by happenings on Massey Agricultural College farm. Lambs were pastured from birth on the College dairy farm in paddocks which had not been grazed by sheep since it had been sown approximately three years previously. These lambs contracted infections of *Cooperia oncophora, C. punctata* and *Ostertagia ostertagi,* although these species have not been found in sheep in the closely adjacent and similar pastures of the College sheep farm. It is concluded that this is a case in which there had been incomplete distribution of the species mentioned.

It is possible that in the cases of other species a similar explanation will account for the low incidence experienced.

Nematode Infection of Sheep in Manawatu District Compared with that in Great Britain and Tropical Countries.

From the point of view of the range of species of nematode found in sheep in Manawatu, it is apparent that there is similarity between this district and a number of other sheep raising countries, and particularly Great Britain and Australia. However, when the relative numbers of individuals of the different species are considered, it is seen that there are

differences. The generalisation may be made that worm infestation of sheep in Manawatu district resembles that found in other temperate countries, while it differs both in point of species and numbers of individuals of different species from what occurs in tropical and sub-tropical countries, *e.g.*, Kenya, South Africa, and parts of Australia. As indicated earlier, in this account, the extent to which trafficking in sheep between New Zealand and these countries has taken place, has had an influence in accounting for these similarities or dissimilarities. Differences in climate, no doubt, have also played their part.

A more detailed comparison of worm infestation in Manawatu with that in Britain, reveals that in the cases of several species, there are resemblances in the order of numbers.

Thus *Ostertagia circumcincta, Nematodirus filicollis, Cooperia curticei, Trichostrongylus vitrinus, T. axei,* are abundant in both countries to much the same degree. The species *Chabertia ovina, Trichuris ovis, Haemonchus contortus, Oesophagostomum columbianum, Cooperia oncophora, Capillaria longipes,* occur in relatively small numbers in both countries. The incidence of *Dictyocaulus filaria* and *Muellerius capillaris* in Manawatu seems to resemble that in parts of Great Britain. Difference in degree of infection relate to only a few species. Thus *Nematodirus spathiger, Ostertagia trifurcata, Trichostrongylus colubriformis,* are abundant in Manawatu, but the available literature makes them appear to be of small numbers in Britain, while *Bunostomum trigonocephalum* and *Oesophagostomum venulosum* would seem to be more numerous in parts of Britain than in this district.

In the warmer climates, South Africa and Australia, *Haemonchus contortus, Oesophagostomum columbianum* and *Bunostomum trigonocephalum* are of greater significance than in Manawatu district. *Cooperia curticei, Trichostrongylus vitrinus, Nematodirus spp,* are uncommon, or occur in smaller numbers in Kenya, South Africa and parts of Australia than in this district.

Conclusion and Summary.

Twenty-five species of Nematode have been found to be present in sheep in Manawatu district. The species of greatest economic importance were found to be in most cases of importance in other temperate climates.

In the cases of certain species, saturation of Manawatu district has not yet occurred, *e.g.*, in the cases of *Cooperia oncophora*, *C. punctata* and *Ostertagia ostertagi*.

The countries of origin of the foundation stock have limited the number of species. Most of the importations have been made from Britain and Australia.

As few nematodes of the sheep require intermediate hosts, their entrance to a new country, New Zealand, has not been prevented to any extent on this ground. *Muellerius capillaris* has been able to survive on account of the abundance of its normal host, which has been introduced also.

The climate of Manawatu is such that the extremes of summer and winter are not severe enough to exert complete control on the various species. Infective stages are well able to survive these less favourable periods. The climate is sufficiently equable to enable out of door pasturing throughout the year, so that in the cases of most species of nematoda infection it is possible also throughout the year.

The farming systems in vogue involve almost solely the use of permanent pasture which is mostly of high carrying capacity. This enables concentration of stock and in conjunction with continuous grazing throughout the year, enables the excessive multiplication of the various species of nematodes.

The prominence placed on the fat lamb industry means that much attention is devoted to the raising of a population susceptible to worm infection.

A prevailing practice is to introduce culls from the surrounding hill districts for purposes of fattening, and sheep from the Hawke's Bay district in time of drought. There is consequently a continual introduction of parasites in these animals.

Cattle are the chief reservoir hosts of nematodes of sheep in Manawatu district. These occur in large numbers in the district and frequently dairying is combined with sheep farming, so that they become important sources of infection to sheep in respect to some species of worm, *e.g.*, *Cooperia oncophora*, *C. punctata* and *Ostertagia ostertagi*.

It would seem that the tendency in the district is towards the increasing of the carrying capacity of pasture. This should result in the multiplication of parasites, particularly Nematodes, to a greater extent than has been the case.

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Some Points in the early Development of *Cysticercus pisiformis* (Bloch 1780).

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The general outlines of the life history of *Taenia pisiformis* (Bloch 1780) in the dog and the rabbit have long been well known. The following reinvestigation of the early stages of the development of *Cysticercus pisiformis* in experimental rabbits was undertaken with the primary objective of checking or refuting the " division " of the Cysticercus described by Moniez in his classical monograph on the Cysticerci, published in 1880.

The work was done under the supervision of Professor Ch. Joyeux, in the Department of Parasitology of the University of Marseilles and I take this opportunity of expressing my great indebtedness to Professor Joyeux for suggesting the work and for providing me with the necessary facilities in his laboratory.

Experiments.

During routine autopsies carried out on three dozen dogs from the town of Marseilles the adult of *Taenia pisiformis* was frequently met with. Ripe segments were fed to rabbits as soon as possible after removal of the tapeworms from the dogs. The rabbits were autopsied at various intervals after feeding and the liver examined for migrating larvae. Small pieces of liver were fixed for sectioning in Bouin's picro-formol and stained with Eosin and Haematoxylin. Entire lobes of the liver were preserved as specimens by fixing in a mixture of equal parts of 95% alcohol, pure

glycerine and 40% formaline and later transferred to weak formaline. Cysticerci were satisfactorily fixed in formol-alcohol (9 parts of 95% alcohol to one part of 40% formaline) and later preserved in glycerine alcohol.

The following experimental results were obtained :—

Rabbit A.—Autopsied on the twenty-first day after being fed about half a dozen ripe segments of *T. pisiformis*. The liver showed an intense infection with developing Cysticerci and was literally riddled with sinuous, thick-walled galleries made by the wandering larvae. The body cavity was full of larvae, which, having escaped from the liver, were beginning to assume the typical bladder appearance. These larvae measure about 4–7 mm. in length and are densely scattered with calcareous granules. They show a cephalic primordium and invagination but no rostellar hooks. At least one cysticercus had found its way into the lungs of this rabbit. There was no natural infection with mature cysticerci.

Rabbit B.—Autopsied 23 days after being given a suspension of *T. pisiformis* eggs in water. It showed only a scanty hepatic infection and there were no developing larvae free in the peritoneal cavity. The hepatic infection consisted of encysted rather than migrating larvae. Two mature specimens of *C. pisiformis* were recovered in the peritoneal cavity : these certainly belonged to a previous natural infection.

Rabbit C. was given 4 gravid segments and autopsied on the 12th day. The liver showed calcified cysts about 2 mm. in diameter but no developing larvae. In the mesenteries there were one or two mature cysticerci.

Rabbit D. was given three gravid segments twelve days before autopsy. The larvae were developing actively in the liver and the winding channels due to their migrations were clearly visible on its surface. Teased out and mounted, the larvae measured 1·5–1·89 mm. long. The infection was a moderately heavy one, and there were no mature cysticerci in the mesenteries.

Rabbit E. was a pregnant doe autopsied on the 14th day after infection. The liver contained a few calcified cysts only and no mature cysticerci were found.

Rabbit F. was given two or three ripe segments and autopsied on the 15th day. The liver and peritoneal cavity both showed very heavy infections with actively developing larvae and there was no sign of calcification. Larvae excised from the liver measured 3–6 mm. in length,

Those which had already escaped into the peritoneal cavity were 5–7 mm. long. The appearance of the liver was as in rabbit A. The migration of the larvae from the liver into the mesenteries was well advanced so that under favourable conditions this would probably begin towards the end of the second week after infection.

Rabbit G.—Autopsied on the 17th day after feeding. The cysts and channels in the liver were all calcified and no living larvae were found in the liver pulp. The mesenteries showed a natural infection consisting of three cysticerci. The conditions under which F. and G. were infected were exactly similar and the different result can, in the writer's opinion, only be explained by assuming that the natural infection in G had rendered it refractory to a subsequent infection.

Rabbits H. and J. were also autopsied on the seventeenth day after infection. H showed signs of hepatic infection with active larvae but none were actually isolated by teasing the liver tissue and calcification had set in. One maturing larva had left the liver and migrated to the surface of the stomach. Rabbit J, which contained 2 mature cysticerci in the mesenteries, showed only 2 or 3 calcified cysts in the liver.

Rabbit K.—Four ripe segments were given to this rabbit, a female, on February 9th. A fortnight later she was placed with a male and coitus occurred between the 23rd and 25th February. A second infection, consisting of three ripe segments, was given per os on March 9th. Parturition occurred on March 28th, 19 days after the second and 47 days after the first infection. Mother and offspring were autopsied within 12 hours of parturition. The young were all healthy—there was no indication of pre-natal infection with cysticerci. The mother showed a heavy hepatic infection with degenerating cysts and also had two mature cysticerci in the mesenteries. These may have constituted a natural infection or may have arisen from the first artificial infection. No importance can be attached to the negative finding in the embryos in view of the double infection.

From these results the following observations emerge :—

I. Division.

In 1880 Moniez described (p. 26) and figured (Pl. 1) a process of division in *C. pisiformis*. According to this investigator larvae about 10 mm. long, divide into two equal parts 22 days after infection. At first they remain

attached to one another by a twisted thread but later they separate and the part budded off degenerates. In the experiments described larvae representing the 12th, 14th, 15th, 17th, 21st and 23rd day of development after infection were examined :—(1) teased out of the liver, (2) free in the body cavity and (3) in liver sections. In no case was any sign of division observed nor did the longitudinal sections of developing Cysticerci show any indication that division had taken, or would take, place. In the writer's opinion, corroborated by Professor Joyeux, this strongly suggests that the observations of Moniez in this matter are either erroneous or descriptive of an isolated or abnormal phenomenon. Moniez's account has, however, been quoted more or less verbatim in the text books of Railliet (1895, p. 219) and Brumpt (1910, p. 167) and has thus been generally accepted, at least by French Parasitologists.

II. Immunity.

Miller and Kerr (1932) found that a considerable degree of immunity to subsequent infection with *C. pisiformis* could be obtained by injecting rabbits with 2 cc. of a 1% suspension of freshly powdered *T. pisiformis* in physiological saline injected either intra-peritoneally, subcutaneously or intravenously ; the injections being given six times, at intervals of 2–3 days, 3–19 weeks before infections. Subsequently, development of *C. pisiformis* was totally inhibited in a few injected animals and all data indicated at least partial immunisation in the injected rabbits. The authors continue " . . . a number of animals were found to have been infected previously to purchase. When this occurred among controls some evidence of a degree of protection against superinfection was observed." It will be observed that, in our investigation, the four rabbits (A, D, F, H) which showed the most intense artificial infections at autopsy, were free from any sign of previous natural infection with *C. pisiformis*. On the other hand, rabbits B, C, G, J and K all had natural mesenteric infections with one or more cysticerci and it was in these rabbits that the infection appeared to have been checked at the hepatic stage and followed by calcareous degeneration of the invading larvae. The only animal which did not fit in with these observations was the large doe rabbit E, in which the infection was checked and calcification had set in although there were no mature cysticerci in the mesenteries. In no case were there more than three mature cysticerci present : it would therefore seem that

even a very small previous infection suffices to render the rabbit at least partially refractory to a subsequent superinfection.

III. Association with Bacteria.

Professor Joyeux carried out tests for bacteria in the cysts formed by the degenerating larvae and in the surrounding hepatic tissue. The results were all negative : there was no indication that these cysticerci might introduce bacterial infections.

Figs. 1 & 2. Larvae teased out of liver on the 12th day.

IV. Pathology.

The infected rabbits remained outwardly in good health and continued to feed.

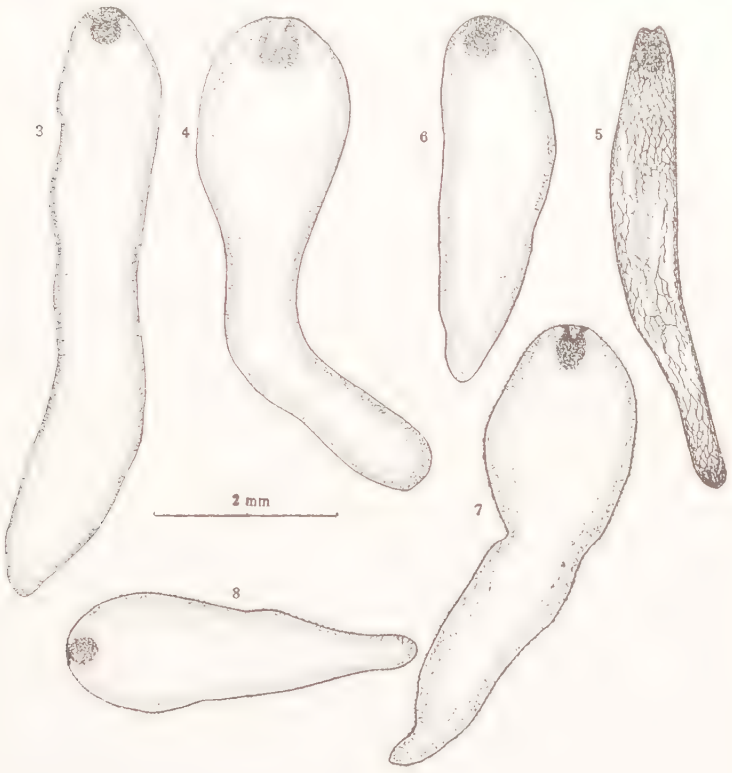
Histological study corroborates the observation of Moniez (p. 24) that the nodule marking the position of the developing larva in the liver is entirely formed from fibrosed liver cells and has no organic connection with the parasite. In sections taken 15 days after infection, the fibrosis

had hardly commenced but there was a dense infiltration of leukocytes, chiefly lymphocytes and eosinophils. The zone of fibrosis enclosing the larva was well marked by the twenty-first day when a section of a nodule shows the young Cysticercus surrounded by a narrow zone showing karyolysis and mechanical breakdown, then a zone of fibrosis and then an area full of infiltrated small round cells merging imperceptibly into a zone of healthy liver cells. The local eosinophilia in the neighbourhood of each parasite is very striking. Between the liver cells and the zone of fibrosis there occur clumps of nuclei, apparently separated from their cytoplasmic units. These grape-like bunches of nuclei are very characteristic and show a close resemblance to the nuclei of the liver cells. It appears possible that degeneration of the extra-nuclear portion of some liver cells might occur while the nuclei remain intact and aggregate into clumps. Sections through the calcified cysts show the fragment of the degenerating larva in the centre and a mass of small round cells among which individual eosinophils are no longer distinguishable. Outside this there is a narrow zone of fibrosis. The giant cells figured by Brumpt (p. 168) did not appear to be present. A section through a cysticercus which had found its way into the lung shows a surrounding zone of hypertrophied tissue and a normal round cell infiltration but no local eosinophilia.

V. Summary of Early Development.

After being swallowed by the rabbit the onchospheres migrate from the stomach—not, according to Leuckart, from the intestine—into the portal vessels whence they are carried to the liver where development, or in refractory subjects encystment, takes place. Twelve days after infection the larvae measure 1·5–2·75 mm. long. There are no hooks or penetrating apparatus of any kind but that end of the larva which later will form the scolex is densely granular while the opposite pole, which will form the bladder, is hyaline (Figs. 1 and 2). The larvae wander through the liver, leaving sinuous white galleries with fibrosed walls and by the end of the second week migration from the liver into the body cavity commences. By the 15th day of development larvae from the liver are 3–6 mm. long. The dense mass of cells, which is the cephalic primordium, is clearly visible at one end. The larva is white and opaque and resembles a plerocercoid in its general appearance (Figs. 3 and 4). Once free in the body cavity the larva swells and elongates, while the reticulated parenchyma of which it is mainly composed breaks down in the centre and is replaced by

a hyaline fluid. This is the beginning of the serous liquid which ultimately fills the bladder. A median longitudinal section of a larva from the body cavity on the 15th day (Fig. 5) shows the commencement of a definite cuticular invagination in the region of the cephalic primordium and also



Figs. 3 & 4. Larvae from liver on the 15th day.
Fig. 5. Longitudinal section of larva from body cavity on the 15th day.
Fig. 6. Complete larva from body cavity 15th day.
Figs. 7 & 8. Larva from body cavity on 21st day.

the tissue breakdown described. By the 21st day the calcareous concretions have become denser and larger giving the surface of the larva a distinctly granular appearance (Figs. 6–8). Brumpt (p. 167) states that

the larvae leave the liver about the 30th day but these experiments indicate that under favourable circumstances migration may commence as early as the end of the second week.

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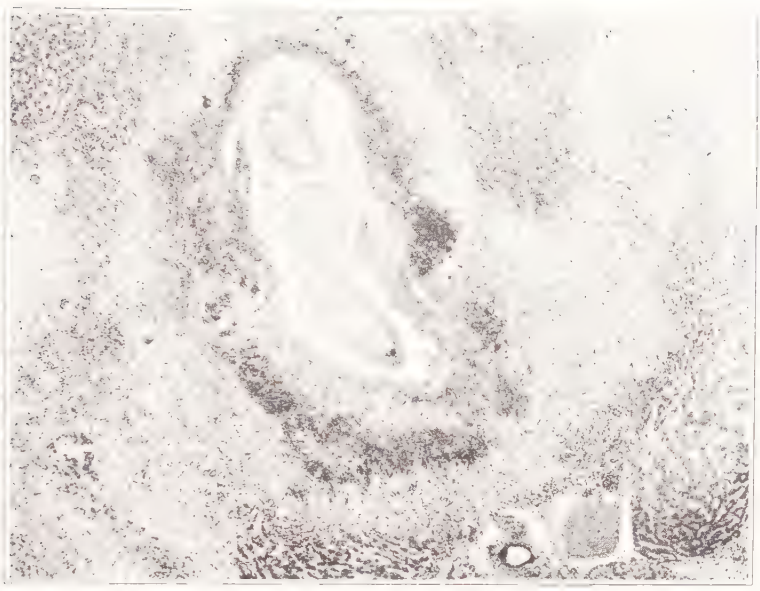
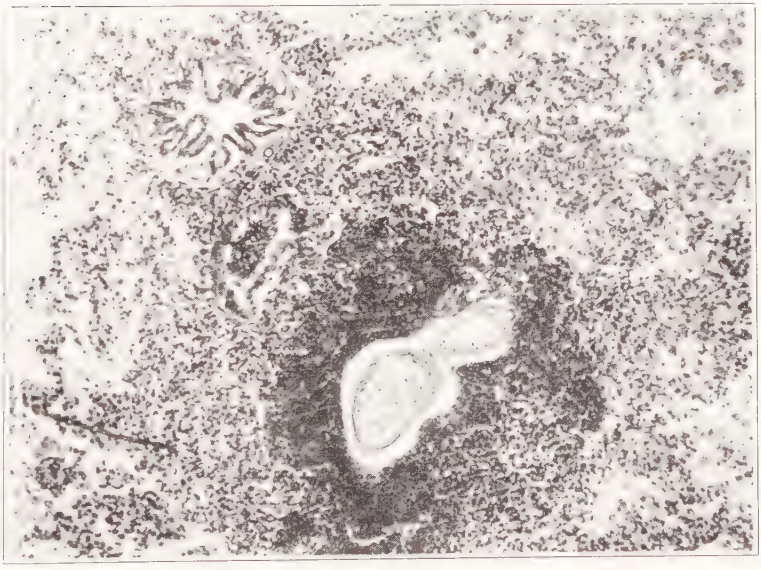


Migration of *Cysticercus pisiformis* through liver in experimentally infected rabbit (x 44.)



Migration of *Cysticercus pisiformis* through lung of experimentally infected rabbit (x 120.)

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Some Parasitic Nematodes from Canadian Fishes.

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Introduction.

The present work forms a continuation of a survey undertaken three years ago, with a view to elucidating the nemic parasites commonly found in fishes of Canadian waters. These species have proved to be largely undescribed, and old species have always offered some new points of interest. The greatest difficulty has been encountered with the literature, much of which was difficult of access. Only those papers which have a definite bearing on the forms studied, and convey some pertinent information, are included in the appended bibliography.

For reasons not at present known, nemic parasites are rare in fresh-water fishes in Canada, while marine forms are fairly common, and of much greater economic importance, as many of them inhabit the flesh of their host, and render it unpalatable. In this connection it is perhaps noteworthy that the incidence of cestode parasites is exactly opposite, they being much more numerous in fresh-water hosts, although perhaps more varied in the marine forms. As it was not possible for the author to make marine collections herself, it was necessary to rely on the generosity of other workers in this respect.

To Dr. Helen I. Battle, who collected material at St. Andrews during the summer of 1933; and to Mrs. E. Kuitunen-Ekbaum, who collected at Nanaimo in 1932, the author offers grateful acknowledgments.

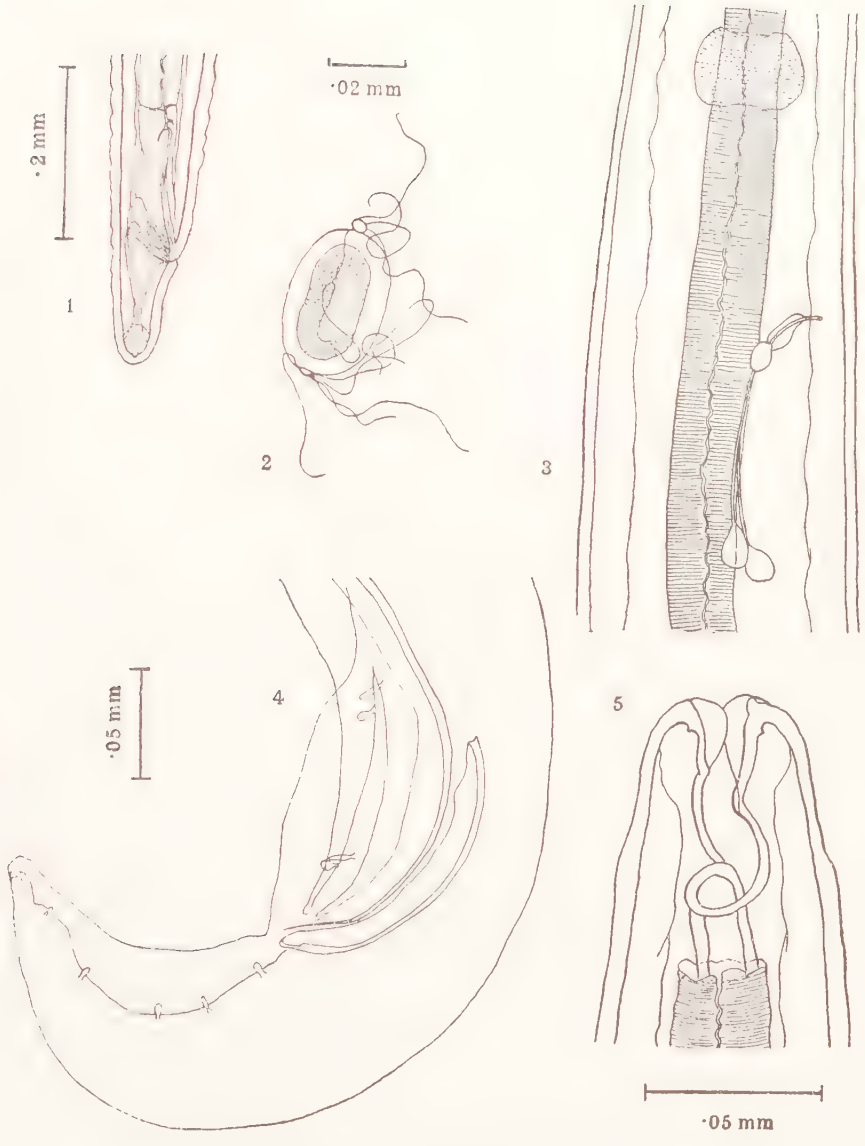
Metabronema wardlei n. sp.

Material:—Three males and nine females, from the gut of *Scorpaenichthys marmoratus*, collected in July 1932 by Mrs. E. Kuitunen-Ekbaum, at the Pacific Biological Station, Nanaimo, B.C.

Slender, filiform worms, the body of uniform diameter throughout, tapering slightly near the extremities. The head is smoothly rounded, the lateral lips are large, the median ones reduced to slender papilliform processes. Six cephalic papillae, two on each lateral lip, one immediately

below each median lip, and readily confused with the latter. The lateral lips have a concave anterior surface. The pharynx is cylindrical, usually coiled to some extent, and, probably because of the coiling, appears extremely short. Its anterior end bears a cup-shaped expansion having the appearance of a small buccal capsule. This capsule is armed with several small toothlike projections. Oesophagus very long, divided into two regions, of which the anterior is short, slender, and of nearly uniform diameter, the posterior much longer and thicker, its diameter increasing posteriorly. It is separated by a distinct valve from the intestine. The rectum is short, muscular, and of smaller diameter than the intestine. The nerve ring is broad and distinct, surrounding the anterior division of the oesophagus. The excretory pore lies usually near the mid-ventral line, slightly posterior to the nerve ring. A short duct opens into an ampulla, from which two fine ducts lead posteriorly for a short distance, each finally ending in one of a small group of pear-shaped bodies. These bodies may be unicellular in character and are reminiscent of the " renettes " of free-living forms. As far as could be determined this is the total extent of the excretory system. The cuticula is finely striated, the transverse striae reaching their greatest width in the region of the anterior division of the oesophagus, decreasing rapidly anteriorly, and very gradually posteriorly. In addition there are numerous fine longitudinal striations, somewhat irregular, and very close together.

Male :—Length up to 23 mm. The testis extends anteriad about as far as the junction between oesophagus and intestine, the anterior portion being folded on itself in various ways, while the larger posterior part is quite straight. The left spicule is very long, slender, apparently flexible, as its anterior half in particular describes a very variable course ; it has the appearance of a hollow tube, its anterior end blunt and opening into a very thin-walled, oval spicule sac ; the posterior end is closed and sharply pointed. The right spicule is short, heavy, and of peculiar shape ; it is fusiform, arcuate, the posterior extremity slender, blunt, slightly clubbed at the tip, the anterior end of much lighter construction, broad, and apparently hollow. Caudal alae well developed, extending from the tip of the tail to the anus, where a slight constriction occurs, and about an equal distance in front of the anus. Anteriorly each is supported by four pedunculated papillae, arranged in two pairs. Posteriorly there are five



Metabronema wardlei n. sp.

Fig. 1, female, lateral view of tail; Fig. 2, egg; Fig. 3, male, nerve collar and excretory system (x290); Fig. 4, male, lateral view of tail; Fig. 5, male, dorsal view of head.

papillae of the pedunculated type, although the posterior two are considerably shorter. The tail is sharply coiled for some distance, and tapers gradually from a point just in front of the anus to the tip, which is blunt and uneven.

A 22·25 mm. male has the following measurements :—Body diameter : just behind the head—0·075 mm ; junction of oesophagus and intestine—0·17 mm. ; anus—0·075 mm. ; the greatest diameter is at the junction of oesophagus and intestine. The oesophagus is about one-fourth the length of the body, measuring 5·7 mm. from the anterior extremity ; its anterior division measures only 0·95 mm. long. The pharynx is very short, being 0·09 mm. long. Diameters of the various regions are :—pharynx—0·016 mm. ; anterior division of oesophagus—0·028 mm. ; posterior division of oesophagus—0·045 to 0·08 mm. ; intestine—0·062 mm. Nerve ring 0·235 mm., and excretory pore 0·35 mm. from the anterior extremity. The cuticular striations are about 8·5μ apart in the oesophageal region, decreasing to 4·5μ near the anus. The anus is 0·185 mm. from the tip of the tail. The short right spicule measures 0·2 by 0·03 mm., the long left spicule is 1·85 mm. long and 0·014 mm. broad ; its wing is 0·016 mm. broad.

Female : Length up to 46 mm. The vulva is approximately three-fifths of the distance from the anterior end in fully mature specimens, further posterior in young worms. Vagina slender, elongated ; it runs posteriad for a short distance, then anteriad for two or three times that distance, dividing at a point in front of the vulva to form the two divergent uteri. The anterior uterus is perfectly straight, except that its tip is reflected. The posterior uterus runs quite straight for a considerable distance, then is followed by a constricted portion which describes a figure-of-8 or other similar looped figure around the intestine ; beyond this the tube continues straight almost to the anus, its very slender tip being reflected. The tail is almost twice as long as it is broad and tapers slightly to a very bluntly rounded tip. The eggs are broadly oval, thick-shelled, with two to four delicate polar filaments arising from a small knob at either end. They contain an early stage of coiled embryo in the terminal part of the uterus.

The following are the measurements of a 45 mm. female :—Body diameter : just behind the head—0·09 mm. ; junction of oesophagus and intestine—0·2 mm. ; anus—0·09 mm. ; greatest diameter—0·205 mm., in region of anterior ovary. The oesophagus is about one-sixth the

length of the body, extending to 7·25 mm. from the anterior extremity ; the anterior division is only one-tenth of this length, and is actually shorter than in the male, being only 0·85 mm. long. The pharynx is the same length as in the male 0·09 mm. Diameters of the various regions are :—pharynx—0·022 mm. ; anterior division of oesophagus—0·03 mm. ; posterior division of oesophagus—0·045 to 0·085 mm. ; intestine—0·065 mm. The rectum is 0·185 mm. long. The nerve ring is 0·25 mm. and the excretory pore 0·37 mm. from the anterior extremity. The cuticular striations reach a maximum width of 12μ at the junction of the oesophageal divisions ; at the anus they have decreased to an average size of 4·5μ. The genital opening is 18·75 mm., and the anus 0·16 mm. from the tip of the tail ; the diameter of the vagina is about 0·045 mm. The eggs vary in size from 0·027 by 0·041 mm. to 0·03 by 0·043 mm. ; the maximum length of the polar filaments is approximately 0·07 mm.

The specimens agree with the generic definition of Yorke and Maplestone (p. 299) in all particulars except that in the males there is no visible gubernaculum, and the left spicule is the longer as in species of *Habronema* ; while in the females the vulva is in the posterior half of the body. This definition was based on Taylor's description of *Habronema magna*, which accordingly became the type species of the new genus.

A second species has been added to this genus by Skinker (1931), under the name of *Metabronema canadense*. The males of this species also have no gubernaculum, although the right spicule is the larger, as in *M. magnum*. In the females, the vulva is near the equatorial region, and the eggs are without polar filaments. The oral aperture is described as simple, inferring that the four lips described by Taylor, and used as a diagnostic character of the new genus, are either not present or are very poorly developed ; the drawings lend support to the former premise.

The differentiation of the genus *Metabronema* seems in fact to rest at present solely on the four pairs of pedunculated postanal papillae of the male, and the fish host. It appears doubtful whether it will be able to retain its ranking as a separate genus, or whether it should not be relegated to that of sub-genus.

Dacnitoides cotylophora Ward and Magath, 1916.

Material :—Sixteen males and thirty-three females, collected on August 5th, and two males and three females on September 15th, 1933, at Port Stanley, Lake Erie ; six males and twenty-four females, collected

September 6th, 1933, at Grand Bend, Lake Huron. Specimens were taken from the intestine of the yellow perch, *Perca flavescens*.

These organisms were described by Ward and Magath in 1916, but several additional anatomical details have now been observed. Internally, the mouth is lined with cuticula produced into denticles along the outer margin (as in *Cucullanus* spp.). There is a pair of long, slender, laterally-placed cervical papillae at the level of the posterior dilatation of the oesophagus. The excretory pore opens mid-ventrally somewhat posterior to the beginning of the intestine. There is a long, slender rectum, with a heavy cuticular lining, discernible in both sexes. The general body cuticula is very thick, hyaline and indistinctly marked with fine transverse striations.

Male :—Body almost straight, or slightly curved dorsally ; posterior to the preanal sucker it is sharply curved ventrally and tapers to a fine point. The testis occupies the posterior two-thirds of the body, and is reflected upon itself, and considerably convoluted. Spicules equal, long, slender, arcuate, delicately pointed posteriorly, extending some distance anterior to the sucker ; gubernaculum present in the form of a short, curved rod, grooved throughout its length and pointed at either end. Small caudal alae extend from in front of the sucker to just in front of the anus ; they are supported by three pairs of pedunculated papillae. In addition there are five pairs of papillae arranged in two straight lines subventrally, from behind the alae to near the tip of the tail, two being anterior and three posterior to the anus. There are also three pairs of small papillae sub-dorsally between the anus and the tip of the tail.

Following are some of the measurements of a 5·7 mm. male :—Rectum 0·14 mm. long, cervical papillae 0·43 mm., and excretory pore 0·74 mm. from anterior extremity. Cuticular striations 5μ apart. Gubernaculum 0·09 mm. long by 8μ wide.

Female :—4 to 6 mm. long. Body straight, or practically so, tapering posteriorly. Vulva at junction of posterior third and anterior two-thirds of body ; vagina directed anteriorly ; uterine tubes straight, filled with eggs, one directed anteriad, the other posteriad, oviducts and ovaries somewhat convoluted. Tail very short and slender, tapering very gradually to its pointed tip. A pair of lateral papillae lie about half-way between anus and tip of tail. Eggs oval, shell twice as thick at poles, unsegmented.

Some of the measurements of a 6 mm. female are as follows :—Rectum 0·17 mm. long, cervical papillae 0·46 mm., and excretory pore 0·82 mm. from anterior extremity. Cuticular striations 4μ apart. Eggs 63·5μ by 46μ. The shell is 4·75μ thick at sides, 8μ at poles.

The only emendation necessary in the generic definition of Yorke and Maplestone (p. 384) is in the description of the male, where the statement " caudal alae absent ; spicules equal ; gubernaculum absent " should be altered to read " small caudal alae present ; spicules equal, gubernaculum present."

Contracaecum magnum n. sp.

Material :—About twenty females and eight males from the Ling Cod, *Ophiodon elongatus*, one of either sex from *Leptocottus armatus*, and three young females from *Apodichthys flavidus* ; collected during the summer of 1932 by Mrs. E. Kuitunen-Ekbaum, at the Pacific Biological Station.

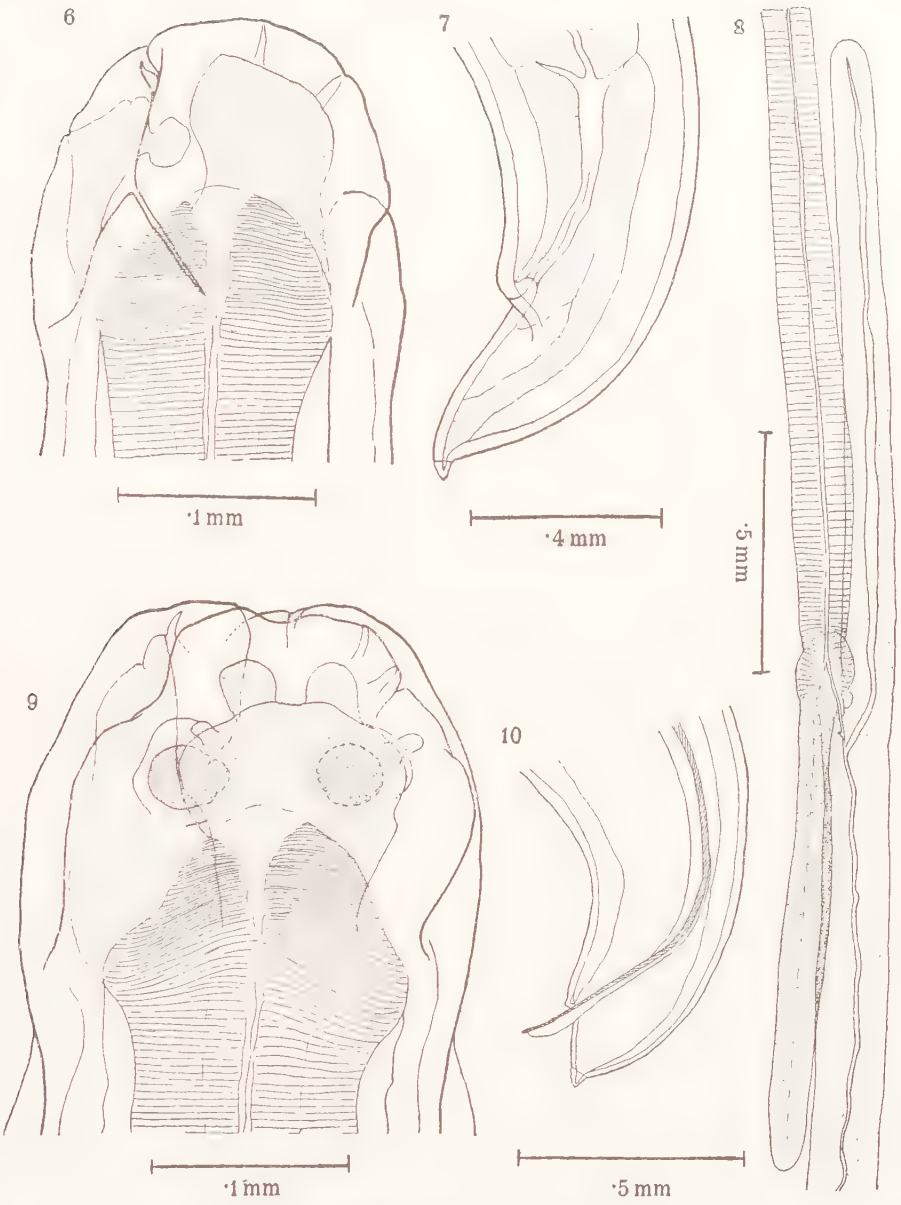
While it is evident that these lots of material belong to the same species, small differences are noticeable. These will be referred to in the text. The most obvious difference is in the size of the head, which in the specimens from *Ophiodon* is large and constricted off from the body, while in those from *Leptocottus* it is small and grades smoothly into the body.

Description of species :—Large stout worms ; the body diameter is greater posterior to the equator, decreasing gradually in either direction. Head large and distinct, *i.e.*, slightly constricted from the body, except in the specimens from *Leptocottus armatus* ; broader than it is long, with a square anterior margin, and broadest at its base. Lips large, powerful, grooved so that they fit very closely together ; they are very heavily cuticulated. In the specimens from *Leptocottus armatus* the dorsal lip is noticeably shorter than the other two. There are four cephalic papillae at the anterior margins of the lips, two on the dorsal, one on each subventral lip. In addition there are two large round papillae with clear cuticular borders, set laterally on the lower part of the subventral lips. Oesophagus long and stout, increasing in diameter posteriorly ; a very small region immediately behind the head, though of the same histological structure, is clearly marked off from the remainder, and should possibly be referred to as the pharynx. A small oval ventriculus is poorly differentiated at the posterior end ; a short, broad, somewhat fusiform appendix

springs from it and lies beside the intestine ; from the anterior end of the latter arises a stout caecum, about half the length of the oesophagus, beside which it lies ; it tapers gradually towards its anterior tip, which is smoothly rounded. The intestine is very thick-walled, of considerably greater diameter than the oesophagus, of uneven outline, and with a small, very irregular lumen. The rectum is short, conical in form, and heavily lined with cuticula ; it is clearly visible in both sexes. The nerve ring surrounds the oesophagus some distance from the anterior end ; it is rather indistinct. The excretory ducts can be seen leading anteriad from the lateral regions of the body, to open just posterior to the nerve ring on the mid-ventral surface. Cuticular striations rather fine, shallow, indistinct, increasing in size posteriorly in the majority of specimens, though in those from *Leptocottus* they are of uniform size throughout the entire length of the worm.

Male :—35 to 93 mm. long. Testis occupies five-sevenths of the body length, all but the most posterior portion being convoluted into a very close pseudo-spiral. The spicules are equal, setaceous, arcuate, winged, the wings being ventral throughout most of their length, but dorsal at the posterior end, and extending around the tip. The anterior end of the spicule is square and broad, the posterior tip slender and rounded ; the spicule is sufficiently delicate to bend readily, as shown by its variable shape. Caudal alae absent, although there are numerous preanal papillae, up to thirty-three pairs. They are very low and flat, successively larger the greater the distance from the anus ; they occupy a ventro-lateral position on the body of the worm, and form a fairly straight line. There are a few poorly differentiated postanal papillae. The tail is a very short blunt cone, surmounted by a slender process. The posterior end of the body describes a single complete turn ventrad.

Following are the measurements of a 93 mm. male from the Ling Cod : head 0·35 mm. long by 0·41 mm. wide. Body diameter : just behind head—0·35 mm. ; level of ventriculus—0·7 mm. ; anus—0·2 mm. ; greatest diameter—1·04 mm. Oesophagus is one-fifteenth the length of the body—6·25 mm. ; of this 0·2 mm is the length of the ventriculus ; the intestinal caecum extends forwards 2·8 mm. ; the oesophageal appendix is 2·1 mm. long. Diameters of the various regions : oesophagus —0·187 to 0·257 mm. ; ventriculus—0·21 mm. ; caecum—0·176 to 0·35 mm. ; appendix—0·176 mm. ; intestine—0·35 mm. The rectum is



Contracaecum magnum n. sp.

Fig. 6, male, lateral view of head; Fig. 7, female, lateral view of tail; Fig. 8, diverticula of alimentary canal; Fig. 9, male, dorsal view of head; Fig. 10, male, lateral view of tail.

0·47 mm. long. The nerve ring is 1·29 mm. and the excretory pore 1·35 mm. from the anterior extremity. The cuticular striations are 3·5μ apart near the head, increasing to 6·5μ near the tail. The anus is 0·176 mm. from the tip of the tail. The spicules are 3·5 mm. long by 0·022 mm. wide; their wings are 0·068 mm. wide. The papillae extend 2·5 mm. anterior to the anus.

Female:—42 to 102 mm. long. Vulva is approximately two-sevenths of the distance from the anterior extremity; vagina runs straight posteriorly, dividing to form the two uteri, which also run posteriorly, so that none of the genital organs lie anterior to the vulva. The uteri are both much convoluted and extend almost to the anus. The tail is a little longer than in the male, though the terminal process is smaller; the anus is deeply constricted. The eggs are small, irregular.

The measurements of an 83 mm. female from the Ling Cod are as follows: head is 0·29 mm. long by 0·35 mm. wide. Body diameter: just behind head—0·32 mm.; level of ventriculus—0·64 mm.; anus—0·32 mm.; greatest diameter—1·1 mm. Oesophagus about one-fourteenth of the body length—5·75 mm.; ventriculus is 0·23 mm. long; caecum—2·34 mm. and appendix 1·46 mm. The following are the diameters of the various regions:—oesophagus—0·16 to 0·32 mm.; ventriculus—0·23 mm.; caecum—0·15 to 0·2 mm.; appendix—0·08 mm. (tip); intestine—0·47 mm. The rectum is the same length as in the male, 0·47 mm. Nerve ring and excretory pore both 1·05 mm. from the anterior extremity. Cuticular striations 5·5μ apart at head, 9μ at tail. The genital opening is 25 mm. from the head.

Contracaecum melanogrammi n. sp.

Material:—Two males and four females from the intestine of the haddock, *Melanogrammus aeglefinus*. Collected August 30th, 1933, by Dr. H. I. Battle, at the Atlantic Biological Station, St. Andrews, N.B.

Large, very stout worms, their greatest diameter somewhat posterior to the equator of the body, tapering gradually in either direction. Head small, somewhat square in outline, broader than it is long, and of smaller diameter than the body immediately behind it; no marked constriction between head and body; the dorsal lip is slightly shorter than the two subventral lips; interlabia, particularly the median ventral one, comparatively small, having the form of a right-angled isosceles triangle; cephalic papillae small, on the antero-lateral surface of the head; each is

enclosed in a marked depression of the cuticula, oval in shape, its long axis transverse ; the dorsal lip bears two, the two subventral lips one each, on their ventral halves. Oesophagus very long, increasing in diameter posteriorly ; no pharynx visible ; the ventriculus is poorly differentiated ; intestinal caecum and oesophageal appendix of almost equal length, the latter being somewhat the shorter ; both are stout, well-developed. Intestine of considerably greater diameter than the oesophagus, smooth-walled, its cells clearly visible in many cases, its lumen narrow, wavy. Rectum long, rather indistinct in both sexes ; its cuticular lining is not notably heavy ; a conspicuous muscular band joins its anterior portion to the dorsal body wall. The nerve ring is slender and indistinct ; it surrounds the oesophagus at a comparatively high level. The excretory pore opens to the exterior at a point either just anterior or just posterior to the nerve ring, on the midventral surface ; in this connection it is noteworthy that in nearly all specimens of Contracaecum used in the present study, the excretory pore is further anterior with respect to the nerve ring in the female than it is in the male. Cuticular striations fine, indistinct, increasing slightly in size towards the posterior end.

Male : 34 and 45 mm. long. Testis occupies the posterior four-fifths of the body length, the posterior portion, distinguished as the ejaculatory duct, being perfectly straight, and very broad ; this is followed by a loosely convoluted portion, the seminal vesicle, of considerably smaller diameter ; the narrow testis proper occupying the most anterior position in the body, and being coiled into a tight pseudo-spiral. Spicules equal, arcuate, very slender, their anterior ends heavily clubbed, their posterior tips smoothly pointed, slightly indented ; they bear ventral wings which gradually decrease in width towards the posterior tip ; a tiny flange extends beyond the tip ; spicule sac large, roughly oval in shape, truncated anteriorly. No caudal alae ; preanal papillae numerous, up to twenty-eight pairs ; they are broadly conical in shape, sharply pointed, each projecting into the centre of a sharply demarcated depression of the cuticula ; they increase in size anteriorly, occupying a straight line on the ventro-lateral surface of the body ; postanal papillae could not be demonstrated. The tail is short, rounded, conical, surmounted by an irregular pointed process. The posterior end of the body describes a single complete turn ventrad.

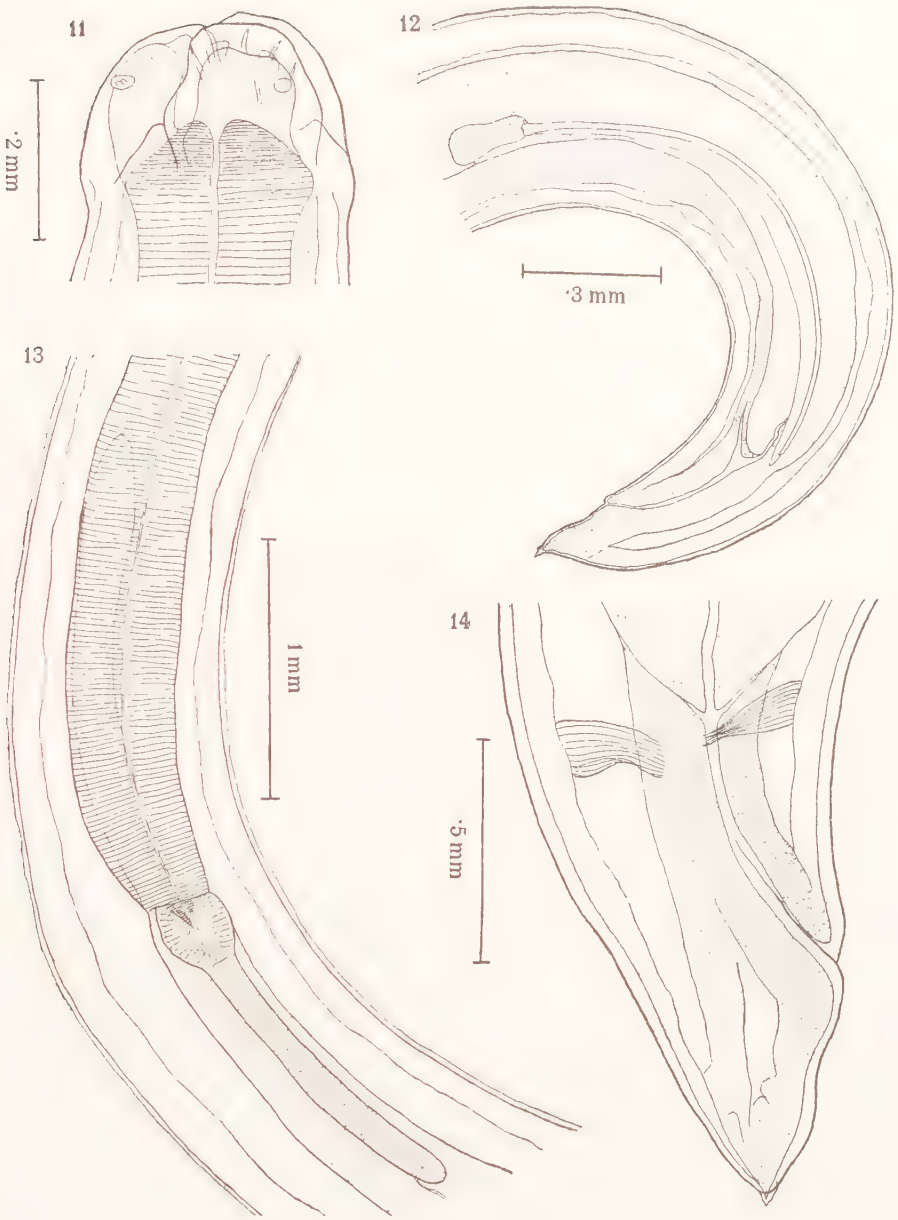
The measurements of the 45 mm. male are as follows :—head 0·18 mm. long by 0·26 mm. wide. Body diameter : just behind head—0·32 mm. ;

level of ventriculus——0·7 mm. ; anus—0·23 mm. ; greatest—0·98 mm. Oesophagus is one-eighth of body length, 5·62 mm. ; of this the ventriculus measures 0·33 mm. ; the intestinal caecum is 1·64 mm. long ; the oesophageal appendix 1·52 mm. long. Diameters of the various regions are :—oesophagus—0·18 to 0·28 mm. ; ventriculus—0·22 mm. ; caecum —0·18 to 0·25 mm. ; appendix—0·2 mm. ; intestine—0·47 mm. The rectum is 0·5 mm. long. The nerve ring is 0·88 mm. and the excretory pore 0·92 mm. from the anterior extremity. The cuticular striations are 4·8μ apart near the head, 5μ near the tail. The anus is 0·211 mm. from the tip of the tail. The spicules are 2·1 mm. long ; near the anterior end they are 0·016 mm. broad, and their wings 0·04 mm. wide. The papillae extend 2·3 mm. anterior to the anus.

Female :—57 to 70 mm. long. Vulva opens two-sevenths of the distance from the head. The body bears a noticeable constriction at this point ; the vagina runs posteriorly, is slender, muscular ; the uteri extend posteriorly and are quite straight ; the ovaries and oviducts are much convoluted. As in *C. magnum* none of the reproductive organs lie anterior to the vulva. The tail is exactly as long as it is wide, in the form of a cone with a slightly undulating outline ; it is surmounted by an irregular process similar to that of the male. The eggs are fairly small, irregular in shape, very thin-shelled.

Following are the measurements of a 70 mm. female :—head is 0·26 mm. long by 0·37 mm. wide. Body diameter : just behind head—0·4 mm. ; level of ventriculus—0·9 mm. ; anus—0·52 mm. ; greatest diameter—1·43 mm. Oesophagus is about one-eleventh of the length of the body, 6·14 mm. ; ventriculus—0·29 mm. ; caecum—1·93 mm. ; appendix—1·58 mm. Diameters of various regions : oesophagus—0·21 to 0·42 mm. ; ventriculus—0·34 mm. ; caecum—0·22 to 0·25 mm. ; appendix—0·23 mm. ; intestine—0·54 mm. The rectum is 0·7 mm. long. The nerve ring is 0·88 mm. and the excretory pore only 0·82 mm. from the anterior extremity. Cuticular striations 4·5μ apart at the head, increasing to 5·75μ at the tail. Anus is 0·52 mm. from tip of tail. The genital opening is 20 mm. from the head.

These worms can be quite readily distinguished from specimens of *C. magnum*. For instance, in the females, the following differences are obvious :—the shorter, stouter form of the body, the smaller head, the greater length of the oesophagus, the constriction of the body at the



Contracaecum melanogrammi n. sp.

Fig. 11, female, lateral view of head; Fig. 12, male, lateral view of tail; Fig. 13, diverticula of alimentary canal; Fig. 14, female, lateral view of tail.

vaginal opening, the greater length of the rectum and its obscurity ; also by the strong muscle band running from the rectum to the body wall, and by the shorter tail. The males are marked off quite clearly by the same general characteristics as the female, the small head, etc., and by the apparently greater sturdiness of the spicules (in neither specimen do they show any sign of bending) and by their simpler wings ; by the distinctive form of the preanal papillae and the extremely short tail. The anus is not so pronouncedly excavated in either sex.

Larval Forms.

In nearly all the material examined, larval nematodes occur, and in many cases far exceed the adults in numbers. It is impossible to determine, without an intensive field survey, whether these forms when mature are parasitic in their fish host, or whether they attain full development only when ingested by some fish-eating animal or bird, or predatory fish.

Contracaecum sp.

Hosts :—*Clupea pallasii* (very heavy infection), *Ophiodon elongatus*, *Scomber* sp., *Merluccius productus*, *Hydrolagus colliei*, *Citharichthys stigmaeus*, *Squalus sucklii*, *Sebastodes* sp. Probably occur in both intestine and body cavity, in the latter as " Ascaris capsularia."

Locality. Pacific Biological Station, Nanaimo, B.C.

The only larval form found to be common in fish from Pacific coastal waters is an ascaroid ; the majority of the specimens have a gut with no diverticula, but with the long, oval ventriculus characteristic of *Anisakis* and *Paranisakis*, parasites respectively of fish-eating mammals and birds, and of fishes. Some of the specimens, however, and usually those in a somewhat more advanced stage of development, show a short intestinal caecum lying beside the oesophagus. A rod of yellow, granular cytoplasm is usually visible in these specimens lying beside the anterior portion of the intestine, the position occupied by the oesophageal appendix of specimens of *Contracaecum*. A careful microscopical examination occasionally reveals the presence of a narrow lumen running through the centre of most of this rod ; it is usually quite unattached to the ventriculus, and its lumen is never continuous with that of the latter. It seems conceivable, therefore, that these are the larvae of a species of *Contracaecum*, and furthermore, that the oesophageal appendix develops, not as a diverticulum of the ventriculus, as might be supposed from its adult form, but by fusion of a separate structure with the ventriculus.

Length up to 35 mm. Small, fairly stout worms, of almost uniform diameter, with coarsely striate cuticula. The mouth is simple, with a few small papillae. Oesophagus long, differentiated into an anterior muscular portion, and a posterior glandular ventriculus, of greater diameter and about half as long. Intestine broad, its walls thick, the cells tall, columnar, and roughly polygonal in section; intestinal lumen narrow. Rectum short, distinct, with a hyaline cuticular lining. Tail short, blunt, conical, with a delicate end process. Rectum and tail both resemble closely those of *Contracaecum magnum*.

Measurements of a typical specimen 22 mm. long are as follows:— Body diameter: anterior extremity—0·2 mm.; level of ventriculus—0·33 mm.; anus—0·12 mm.; greatest diameter—0·42 mm. Total length of oesophagus is 3·4 mm., the ventriculus measuring 1·2 mm.; diameters of the regions are: muscular oesophagus—0·094 to 0·14 mm.; ventriculus—0·234 mm.; intestine—0·187 mm. The rectum is 0·14 mm. long, and the anus 0·13 mm. from the tip of the tail. The nerve ring is 1·17 mm. from the anterior extremity.

Porrocaecum sp.

Host. *Gadus callarius*, flesh.

Locality. Atlantic Biological Station, St. Andrews, N.B.

The flesh of the Atlantic cod, *Gadus callarius*, is heavily infected with large stout ascaroids; the worms possess a long ventriculus, and an intestinal caecum of varying length springs from the anterior end of the intestine and lies beside the ventriculus; there is no trace of an oesophageal appendix. Because of lack of evidence of the nature of these specimens when mature, and the characteristic *Porrocaecum* gut, the name *Porrocaecum* sp. is provisionally applied to them, with the following description:—

Length up to 50 mm. Body long and stout, tapering towards either extremity. Cuticula coarsely striated. Mouth bounded by very small lips, which are, however, typically ascaroid in form and arrangement. Oesophagus fairly short, divided into two regions of different histological nature, the posterior ventriculus about two-fifths of the total length. Intestine broad, of very slender, columnar cells giving a finely striate appearance in optical section; caecum short, stout, varying in length

from about one-third to about three-quarters of the length of the ventriculus; lumen of intestine and caecum fairly large. Rectum short, indistinct; tail very short, conical, pointed.

Following are the measurements of a typical specimen 48 mm. long :— Body diameter : anterior extremity—0·31 mm.; level of ventriculus—0·63 mm.; anus—0·26 mm.; greatest diameter—0·91 mm. Total length of oesophagus is 3·8 mm., the ventriculus being 1·5 mm. long; the intestinal caecum measures 0·95 mm. in length. Diameters of the various regions are : muscular oesophagus—0·14 to 0·25 mm.; ventriculus—0·34 mm.; caecum—0·17 to 0·18 mm.; intestine—0·35 mm. The rectum is 0·23 mm. long, and the anus 0·21 mm. from the tip of the tail.

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A Survey of the Intestinal Helminths of Yakusu, Haut Congo Belge.

By A. C. Fisher, M.B. (Brist.), F.R.C.S. (Eng.).

Yakusu lies on the North bank of the river Congo twelve miles below Stanleyville and the termination of the rapids of Stanley Falls. One of largest tributaries, the Lindi, joins the main stream just above the settlement.

The population under consideration is distributed in villages which are ranged in a single row of huts along the river bank, on either side of the old-established Baptist Missionary Station. The classes of persons included in this survey were children and adolescents of both sexes from the schools of the B.M.S., employees of the station, adult men of the Turumbu forest tribe and fishermen of the Lokele tribe, which last were in the majority. There appeared to be some kind of taboo which made adult women unwilling to bring specimens, unless they considered themselves ill.

With the exception of the children in the boarding-schools, the mode of life in these various groups, in its bearing on intestinal helminthiasis is essentially the same. The huts lived in are of a squalid type, usually in a state of bad repair ; they provide an ideal refuge for multitudes of house rats. Food and drinking water are kept in wide-mouthed vessels covered with a few leaves. The staple article of diet is plantain, which is either eaten by itself or in conjunction with manioc. Fish figures largely on the menu and is usually boiled. Meat is less commonly available except amongst the forest people. The habit of eating flesh in a raw state does not seem to occur in this locality. This practice is quite common among some of the tribes near Lake Albert, where cestode infestations are consequently high.

The mode of faecal disposal is of interest. Both sexes habitually defaecate into the river, or into one of the creeks, following the act with anal ablution. Owing to the sluggish current this faecal matter collects in a scum along the water's edge in the neighbourhood of villages : a feature, however, which in no way deters the inhabitants from bathing. Water for cooking is taken from such contaminated sources but all except a few unwary children drink either in mid-stream or from forest springs.

The following method was used in examining faecal specimens : Natives were instructed to bring a portion of the hardest part of the scyballum, the outside of which was scraped with palm-fibre spatulas, and two films made with normal saline. A complete examination was made of each of these preparations. This simple procedure was used because of the high proportion of positive results obtained for intestinal schistosomiasis, which was the primary object of the investigation. For the intestinal parasites the method cannot be regarded as being so accurate as the various modifications of the floatation technique. The figures, therefore, that are given below are all lower than the true value.

Ascaris lumbricoides.

The reason for the high infestation-rate with this parasite is easily apparent. During the act of anal ablution the hand must frequently become contaminated with the sewer-like water of the river margin and the same hand subsequently used in eating without the aid of spoon or fork. Ova may similarly be picked up and remain under the finger-nails during bathing.

How far the rate of *Ascaris* infestation is an index of the standard of domestic hygiene is suggested by a comparison of the general figures with those of the boarding-school, where living conditions are good and infestations minimal.

Hookworm.

The incidence of hookworm is relatively low and infestations sufficiently severe to cause obvious anaemia were not commonly met with. It was not found possible to estimate the influence of this parasite on the general health of the community, but in the case of school children some information is available.

The register of attendance of the infants' school at Yakusu shows that in one term the average number of attendances for each of 79 children who showed hookworm ova in the faeces was 89 days. The average number of attendances for each of 112 children whose stools were negative for hookworm ova was 95 days. These two groups are strictly comparable from the point of view of age, tribe, and distance of the home from school, so that the discrepancy of one week in the figures cannot be without significance. These mild infestations in children probably affect the health by lowering the resistance to the malaria which they all harbour.

Table embodying results of faecal Survey. Arranged in age groups.

Age period	*Ascaris.* Number per cent.	*Hookworm.* Number per cent.	Both *Ascaris* and *Hookworm.* Number per cent.	*Trichuris trichiura.* Number per cent.	*Oxyuris vermicularis.* Number per cent.	*Strongyloides stercoralis.* Number per cent.	Free from infestation Number per cent.
1st decade (288 persons)	66	37	30	1·5	1·5	0·75	25
2nd decade (268 persons)	63	46	30	3·0	0·5	1·0	16
3rd decade (337 persons)	57	33	13	1·75	0·3	1·0	23
4th decade (62 persons)	51	32	16	0·0	0·0	3·0	33
Girls boarding school) (51 persons)	10	4	2	0·0	0·0	0·0	90

Hymenolepis diminuta. 7 cases encountered in all.

Oxyuris vermicularis.

During a sigmoidoscopic examination of a case of bilharziosis some mucus was removed from the pelvic colon. On microscopic examination this proved to contain the ova of *Oxyuris vermicularis* in large numbers closely clustered together.

Trichuris trichiura.

Adult parasites were occasionally recovered following treatment with carbon tetrachloride.

Strongyloides stercoralis.

The incidence of this helminth was found to be rather variable. In one group of fishermen (not included in this survey) larvae were found in nearly 40% of a small series of cases.

Hymenolepis diminuta.

The seven cases of infestation with this parasite included children and adults of both sexes. Ova were always scanty, so that it is probable that, had a more specialized technique been employed the number of cases would have been considerably larger.

As has already been pointed out, the conditions under which the natives keep their food and drinking-water easily allow of contamination by rats and their fleas. These rats are heavily infested with *H. diminuta* and one adult female examined by Dr. Chesterman actually harboured as many as 18 adult specimens of this cestode. It is to be noted that *H. nana* was not once encountered.

Taenia echinococcus.

Parasitic cysts due to this cestode were encountered in a woman of the Kafwankumbi district of the Katanga, Congo Belge. At operation two cysts were removed; one which was imbedded in the Latissimus dorsi muscle was as large as a rugby football, while the other situated in the deltoid was much smaller. Both contained many " daughter " cysts.

Acknowledgments.

The writer wishes to express his indebtedness to Dr. Clement Chesterman, M.D., M.R.C.P., for his wholehearted and painstaking co-operation, and to Mrs. Chesterman for making the examination of school children possible.

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Anguillulina cecidoplastes n. sp., a Nematode causing Galls on the Grass, *Andropogon pertusus* Willd.

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Introduction.

Venkatarayan (1932) gave a short account of the occurrence of galls on *Andropogon pertusus* Willd., a common pasture grass of South India. He described the appearance of the galls, their distribution on the plant, the symptoms to which they give rise and established the fact that the nematode causing them is a species of *Tylenchus* to which, however, he did not give a specific name. He pointed out that there were no earlier records of the occurrence in India of galls on grass or cereals due to nematodes apart from those caused by *Anguillulina tritici* in the ears of wheat.

In the course of correspondence on the subject of these galls, Mr. Venkatarayan very kindly acceded to the writer's request for preserved specimens of affected grass and in due course sent dried infected leaves and galled material fixed in 5 per cent. formalin and on this the investigations recorded in the present paper have been carried out. The writer's cordial thanks are herewith expressed to Mr. Venkatarayan for his great assistance in so generously supplying this material.

General Considerations.

Symptoms and pathology will be dealt with later on but the following particulars about the grass and the galls may be set out here. *Andropogon pertusus* is a comparatively small grass apparently not growing more than 4 to 6 inches high. Its leaves are typically flat and vary in length from 1 to 3 inches. The edges bear minute teeth and there are fine bristle-like hairs irregularly distributed on both leaf surfaces. The galls occur on the leaves, leaf sheaths, stems and on the axis of the inflorescence. On a leaf blade there may be any number from one or two to 30 or 40. They

may be found on any region of the leaf and may be sparsely scattered or closely aggregated and, when numerous, several may be found so close together that their margins coalesce ; the cavities of such contiguous galls, however, remain distinct. Venkatarayan says that when young, the galls are almost colourless but that as they grow older they assume a purple colour towards the centre and this gradually spreads outwards over the whole gall which, when mature, becomes purplish black. This colour may extend beyond the gall into the surrounding tissues of the leaf.

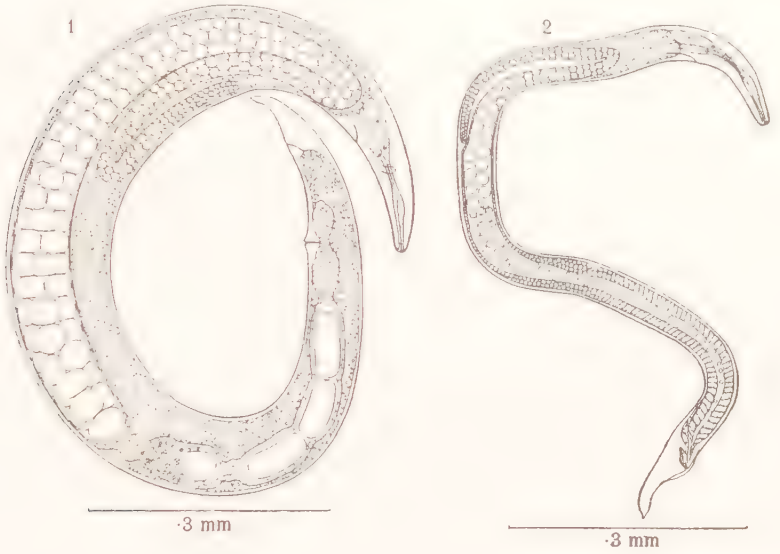
On carefully opening galls under water by means of needles it has been possible to float out the nematodes which occupy the central cavity. Young galls contain developing larvae, older ones, adults, eggs and larvae and mature galls masses of infective larvae together with the distorted empty cuticles of adults. A large number of galls containing adult worms has been dissected and counts made to determine the numbers of adults of each sex per gall. This varies somewhat but most frequently there is only one adult of each sex ; sometimes there are two of each and occasionally three or four males to two females. In one of the largest galls dissected there were four males and five females. Rather infrequently small but well formed galls are found to contain a single worm, either male or female.

Morphology.

Dimensions :—*Female* : length, 1·2 mm. to 2·03 mm., stylet, 8–9μ ; α=18–12·8, β=13–9, γ=31·5–18, V=88·3%–93% ; *Male* : length, 0·97 mm. to 1·33 mm., spicules, 28–30μ, α=29–17, β=7·2–6·5, γ=14–12·4.

In general shape the adults of both sexes rather closely resemble those of *Anguillulina tritici* and *A. agrostis*. The females are always more or less coiled ventrally like watch springs and the body is comparatively stout owing to the great development of the gonad. In both sexes the body tapers from the region of the oesophagus to the anterior end and posteriorly from the anus to the tip of the tail which bears a minute peg-like terminal process. The cuticle is transversely striated. The head has the shape of a flat cap and is separated from the body by a faint constriction. It is not heavily cuticularized but under high magnification the usual six radial ridges can be discerned. The buccal cavity is about as deep as the head and its slightly convex sides are lightly cuticularized.

The stylet is comparatively small, being only 8-9 μ long. It has the structure usually found in species of *Anguillulina*; being made up of a conical anterior half and a cylindrical posterior half bearing three small rounded basal swellings. A slight projection on either side marks the junction of the two parts.



Anguillulina cecidoplastes n. sp.

Figs. 1 & 2. Adult female and male in lateral aspect showing general shape and structure.

The oesophagus differs from that usually found in species of *Anguillulina* in that there is no distinct median muscular bulb. It consists of an anterior fusiform portion which gradually increases in width till, at the region where the rounded or ellipsoidal bulb usually occurs, it is a little more than one-third the corresponding width of the body. After this it narrows gently to the neck region and then expands into the somewhat spatulate posterior glandular swelling. This is composed of the three oesophageal gland cells; a large dorsal gland cell occupying most of the organ and two smaller sub-ventral gland cells, with smaller nuclei, situated to the front of the swelling. The lumen of the stylet is continued backwards into that of the oesophagus into which the dorsal oesophageal gland opens by a short duct a little way behind the base of the stylet.

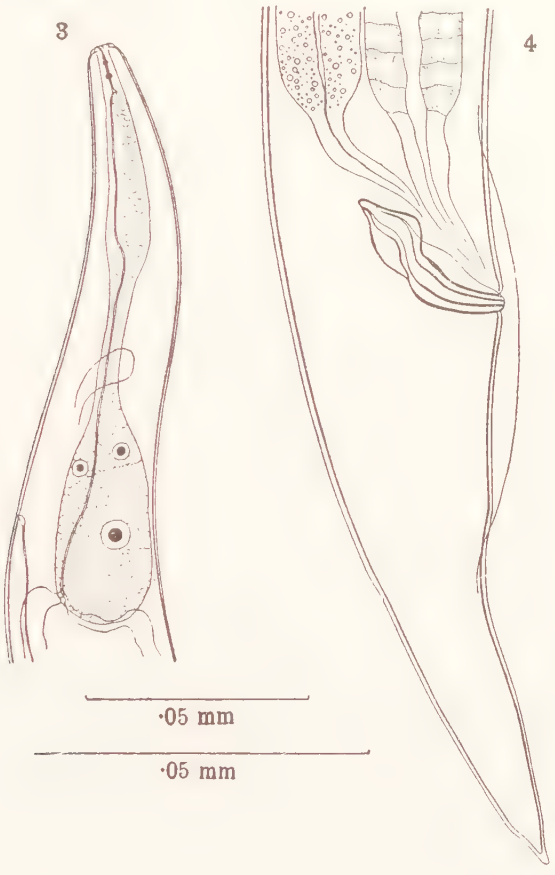
The lumen of the oesophagus is continued throughout the length of the oesophagus as a narrow tube and, in the absence of the median muscular bulb, there are no crescentic thickenings of the wall such as are generally found in the bulb. The openings of the two sub-ventral oesophageal gland cells have been traced, however, to the point where they would open if the median bulb were present. The nerve ring crosses the neck of the oesophagus just anterior to the posterior glandular swelling. The excretory pore opens on the ventral surface in the vicinity of this part of the oesophagus. The intestine is typical and is connected to the anus by a short rectum.

Female :—The gonad is closely similar in structure to that of *A. tritici*. The ovary is large and commences as a blind end directed anteriorly and placed well forward in the body. This limb, containing small rounded egg rudiments, runs backwards for some distance and then, turning forwards by a sharp bend, it reaches the vicinity of the oesophagus. Here it bends back and is continued posteriorly in the body, gradually increasing in width as the eggs grow larger.

It ends in a constriction of its walls which thicken into a kind of cellular sphincter separating the ovary from the swollen receptaculum seminis. The latter usually contains large numbers of round spermatozoa. The receptaculum seminis is to be regarded as a dilatation of the anterior end of the uterus since it is continued posteriorly into the latter which consists of a hollow tube whose walls are made up of numerous epithelial cells. Just anterior to the vulva these cells become very prominent and their rounded inner ends project into the lumen of the uterus and make it quite narrow. Behind the vulva there is a short, thick-walled uterine sac which reaches about one-third of the distance between vulva and anus. There may be up to five eggs at a time in the uterus.

Male :—Adults of this sex are shorter and narrower than females. The testis is single and does not reach so far forwards in the body as the ovary in the female. It is also as a rule folded only once on itself and not twice as is the ovary. In the posterior third, constituting the vas deferens, the walls become comparatively thick and the cells composing them are highly vacuolate in appearance. There is a pair of spicules but a gubernaculum is apparently absent. Each spicule is rather heavily built and when seen in lateral aspect has the shape shown in fig. 4. It consists of a large expanded head portion the sides of which taper towards each

other and meet dorsally in a narrower rounded process. There is a slight constriction separating the head from the shaft which tapers a little to the rather blunt point. Two strengthening ridges extend from the point to the head along the ventral side and on this side also it has been possible to discern a thin membraneous expansion stretching from the head to the



Anguillulina cecidoplastes n. sp.

Fig. 3. Head end and oesophagus in lateral view, highly magnified.

Fig. 4. Male tail in lateral view, showing one of the two spicules and one caudal ala, highly magnified. The upper scale applies to fig. 3, and the lower one to fig. 4.

point of the spicule. Very narrow caudal alae are present on the tail. They arise a short distance in advance of the heads of the spicules and extend to about half way between the anal aperture and the tip of the tail.

Eggs :—The eggs are cylindrical with rounded ends and measure from 85 μ to 100 μ long by 31 μ to 38 μ wide. They are laid in a many-celled stage of segmentation.

Larvae :—The first stage larvae measure from 0·53 mm. to 0·66 mm. long. They are typical in structure ; stylet, oesophagus and intestine being clearly visible. After undergoing a moult these larvae grow in length and become second stage larvae which are markedly similar in appearance to the corresponding larvae on *A. tritici*, *A. agrostis* and *A. graminis*. Such larvae when revived from dried galls and killed by heat measure 0·737 mm. to 0·805 mm. in length. The genital primordium occurs in the usual position about half way down the intestine on the ventral side. Larvae of the second stage occur in large numbers in fully mature galls and constitute the infective stage ; agreeing in this respect with the larvae of *A. tritici*, *A. agrostis* and *A. graminis* but differing from those of *A. graminophila*, *A. balsamophila* and *A. dipsaci* in which the infective stage is the pre-adult fourth stage larva.

Life-History.

Since preserved material only has been examined, the following remarks on the life-history of the parasite are based on inference but at the same time there is no reason to doubt that they are substantially correct. With the fall to the ground of galled and withered leaves the galls will gradually become soft and permit the escape of the contained infective larvae. These will migrate on to young developing grass plants and, making their way to the region of the growing point, will invade the tissues. As the plant grows and the leaves expand the galls caused by the parasites will be carried up and revealed. The worms develop within the cavity formed within the galls and having reached sexual maturity, pairing takes place and the females lay large numbers of eggs. These hatch and give rise to first stage larvae which, as already described, undergo a moult and, becoming second stage larvae, have reached the infective stage and are thus able to carry on the life cycle.

Symptoms.

Venkatarayan says that " affected leaves in bad cases are fully covered up by the galls and sometimes curiously distorted, . . . diseased leaves

sometimes roll so tightly as to hold firmly the tip of the younger leaves. The leaf subtending the inflorescence when severely attacked does not allow the inflorescence to spread out. The leaves finally become yellow and die."

Pathology.

Before considering the structure of the galls and the changes brought about in the tissues as a result of their development, it will be useful first to give some account of the structure of a normal leaf. Transverse sections of the unaffected regions of a leaf blade of *Andropogon pertusus* show that it is made up of an upper and lower epidermis with intervening mesophyll and vascular bundles. There are no palisade cells and air spaces appear to be absent from the mesophyll. In the upper epidermis the cells are noticeably larger than in the lower epidermis and are somewhat rhomboidal in shape. They are arranged in rows of from four to seven large cells with three or four smaller ones intervening and, according to Bews (1929) are to be looked upon as water storage cells. In the lower epidermis the cells are mostly of a uniform size. Very small stomata occur in the lower epidermis and both upper and lower surfaces of the leaf carry scattered bristle-like hairs. There is a weakly developed midrib beneath which runs a strengthening plate of small sclerenchyma cells, shown on the left in Fig. 5. On the upper side of the leaf overlying the midrib and on either side of it, the water storage cells form a kind of flattened plate four or five cells deep in the median line but thinning out on each side to a single cell in depth. At or just below the surface of this plate exactly in the median line there is a row or group of small sclerenchyma cells. On either side of the midrib there are usually three primary vascular bundles and numerous small secondary ones ; 8 or 9 of the latter as a rule occurring in between two primary bundles, though there is some irregularity in this arrangement. The primary bundles have, as a rule, a few small sclerenchyma cells above and below them but the secondary bundles are without them.

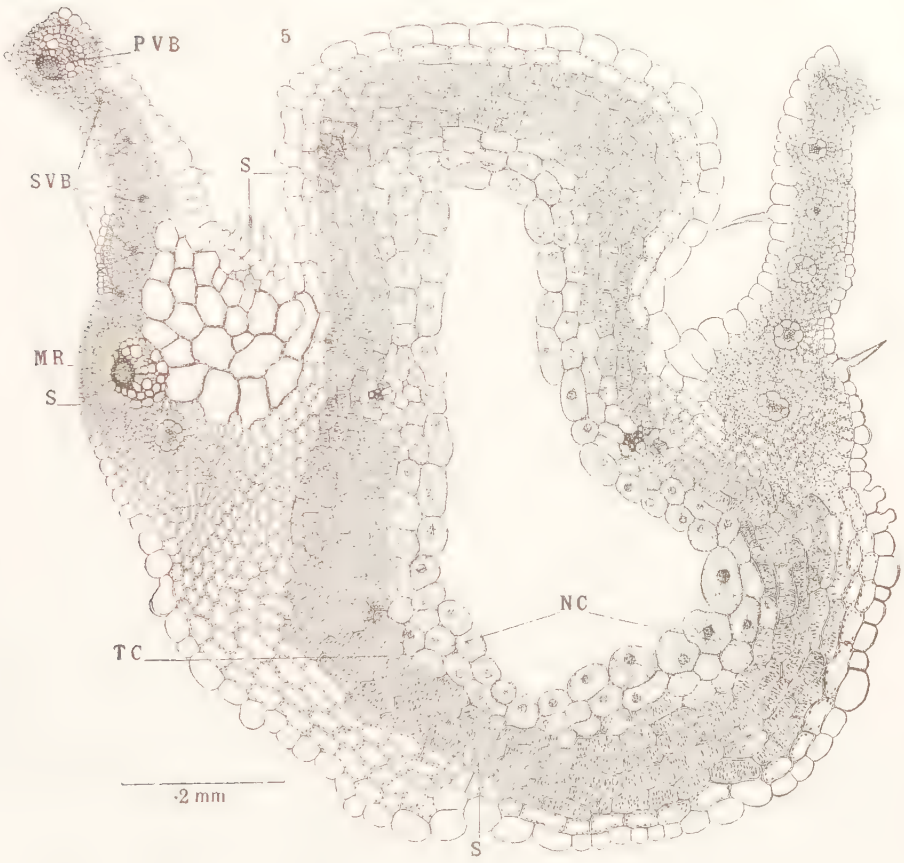
Each secondary bundle is surrounded by a distinct ring of cells whose outer walls are convex, whose contents are granular in appearance ; the granules are composed of starch as is revealed by the iodine test. Starch grains are also present in the ring of cells round each primary bundle. The rest of the area between upper and lower epidermis is occupied by small thin-walled parenchyma cells containing numerous chloroplasts.

The galls are comparatively small structures seldom more than one millimetre in diameter. They are pronounced localized swellings arising steeply from the leaf or other tissues like small warts. For the most part they are rounded in shape and the bulk of each gall protrudes on the lower surface of the leaf ; on the upper side there is usually a somewhat smaller boss or dome of galled tissue. Occasionally the greater part of a gall protrudes on the upper surface. When examined under low magnification, the upper and lower surfaces of a gall are seen to be rather rugose owing to the convex curvature of the outer faces of the enlarged epidermal cells.

A series of transverse sections through young developing galls shows that the first signs of swelling in the tissues are to be found in the mesophyll cells and in the two epidermal layers. The ring of starch containing cells round the vascular bundles appears to change but little either in size or in the number of cells composing it. Neither do the xylem and phloem elements of the bundles appear to undergo any marked increase in size such as the writer has observed in galls on roots attacked by *A. radicicola* (1932) and leaf galls caused by *A. graminophila* (1933). A little deeper into the gall it can be seen that the vascular bundles become displaced laterally and come to lie in its outer layers where enlargement and some displacement of the individual elements composing the bundles takes place. Sections still outside the gall cavity show that the great mass of cells comprising the gall consist of much enlarged mesophyll cells the protoplasm of which is granular in appearance and in which the plastids are rather clumped towards the periphery. The epidermal cells immediately above a gall undergo some multiplication and enlargement forming a layer two to three cells deep whilst those of the lower epidermis become much enlarged and stretched to accommodate the mass of mesophyll cells which are thrust downwards.

When we come to examine a median section of an older well developed gall such as that shown in Fig. 5, it can be seen that the wall is composed of a thick layer of cells, in some places more than 10 cells deep. The innermost nutritive zone lining the gall cavity consists of two or three rows of cells which are greatly enlarged, rounded, ellipsoidal or rhomboidal in outline. Their walls are rather thin and their contents lack chloroplasts but are rich in finely granular, much vacuolated protoplasm. Each cell contains a large round nucleus with two or three nucleoli. Outside this zone we come to another, varying from three to six cells deep, made up of

rather elongate cells the walls of which exhibit reticulate secondary thickenings. Their contents are also highly granular and each contains a large nucleus, not shown in Fig. 5. Here and there amongst these cells occur small groups of enlarged true sclerenchyma cells (S) without cell contents. Separating the thickened layer of cells from the exterior we have another row or two of large mesophyll cells and outside these the



Anguillulina cecidoplastes n. sp.

Fig. 5. Vertical transverse section of portion of leaf and well developed gall on *Andropogon pertusus* Willd., due to *Anguillulina cecidoplastes* n. sp., MR, midrib, NC, nutritive cells, PVB, primary vascular bundle, S, sclerenchyma cells, SVB, secondary vascular bundles, TC, thickened cells.

epidermis which, on the upper side of the gall, may be only one cell in thickness but is sometimes more.

On testing sections of galls with iodine it is found that starch is absent from all the layers. This is understandable when it is recalled that the gall tissues develop from hypertrophied mesophyll cells which apparently contain no starch; this material being confined to the girdle of cells immediately surrounding the vascular bundles.

The tissues composing the gall just described exhibit remarkable modifications both in the size of the individual cells, in their contents and in the structural development of their walls. The changes induced by the parasite are more profound and specialized than in any other galls on grasses due to species of *Anguillulina* whose structure has been studied in detail. In the case of both *A. graminophila* and *A. graminis* the leaf galls show cell multiplication and hypertrophy including enlargement of the vascular bundles. The same holds good for the root galls due to *A. radicicola*. In none of these, however, do we find differentiation of the enlarged cells into an inner specialized zone of nutritive cells surrounded by a zone of cells whose walls are secondarily thickened as in the galls caused by *A. cecidoplastes*.

When it is borne in mind that such an elaborate gall can arise as a result of the presence of a single specimen of the parasite, it seems reasonable to infer that the modification of the host tissues must be due to some other cause than mere mechanical irritation set up by the parasite. The writer, in fact, holds the view that the parasite pours out some diffusible irritant secretion which causes the plant cells to react in such a way that profound morphological changes are induced in them. In this connection it is of great interest to consider the work of Kostoff & Kendall (1929) on the structure and development of certain Cynipid insect galls and their views as to the manner in which such galls are formed.

The structure of the gall caused by *A. cecidoplastes* shows a remarkable resemblance to that found in various Cynipid galls described by Kostoff & Kendall on a variety of host plants. Such insect galls, though exhibiting greater complexity and diversity of structure than that described above, all have an innermost nutritive zone made up of greatly enlarged cells which possess granular contents and have much enlarged nuclei; sometimes they are multinucleate. Outside this is the sclerenchyma zone, composed of cells whose walls become strongly thickened and whose contents are also granular and have large nuclei. The parallelism

between the anatomy of these galls and that caused by *A. cecidoplastes* cannot be taken further but it is interesting to note the fact that in galls of both kinds we have an innermost nutritive zone surrounded by a zone of strong walled cells which show secondary thickening.

A Cynipid gall is to be regarded as the resultant of the action of the parasite and the reaction of the host tissues and the processes involved are discussed at considerable length by Kostoff & Kendall, whose views are briefly somewhat as follows. Irritant substances are localized round the insect egg and later round the larva hatching therefrom ; this is well known from the work of a number of earlier investigators. These substances stimulate the surrounding plant tissues to increased metabolism, *i.e.*, to more rapid growth and increased cell division. The stimulus spreads outwards centrifugally and we get an inner zone where the stimulus is so great as to inhibit cell division. Here the cells are inactivated but remain large and highly granular, the nutritive zone. Outside this we come to a region where the stimulus acts under optimal conditions and here there is great cell activity resulting in much cell division and and hypertropy, these tissues making up the bulk of the gall growth. The stimulating substances cause an inflow of plant nutrients of various kinds into the enlarged cells and these are utilized by the parasite living within the gall cavity. The cavity itself is apparently formed by the lytic action of the irritant substances operating so powerfully as to cause the breakdown of some of the cells in the immediate vicinity of the parasite and by the gradual destruction of the cells of the nutritive zone by the insect larva once it has hatched from the egg and begins to feed. The sclerenchyma zone of Cynipid galls is regarded as being formed by the plant, not as a supporting structure, but as the area in which the plant brings about the neutralization of the irritant substances by its own protective mechanism and thus limits the further growth of the gall.

The processes of gall formation outlined above are most suggestive and, in the writer's opinion, it is highly probable that essentially similar processes operate in the production of galls due to the nematode, *Anguillulina cecidoplastes*.

Host.

Andropogon pertusus Willd., a common pasture grass in South India.

Geographical Distribution.

According to Venkatarayan, examples of *Andropogon pertusus* bearing galls have been obtained from Bangalore, Chikmagalur, Coimbatore and Palghat in South India.

Systematic Position.

There are three anatomical features which distinguish the present species from other members of the genus *Anguillulina* :—1. The absence of a median muscular oesophageal bulb. 2. The absence of a gubernaculum in the male. 3. The shape of the spicules with their blunt points and heavily built heads. These characters are sufficiently distinctive to render it unnecessary to discuss the further differentiation of the parasite from other species of the genus giving rise to galls on grasses, namely *A. graminis*, *A. tumefaciens* and *A. graminophila*. In view of these considerations it is necessary to establish a new species for the worms which are accordingly named *Anguillulina cecidoplastes* n. sp. The writer is indebted to Dr. B. G. Peters for suggesting this name.

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New Names in Vol. XII.

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